THE SPECIALISTS' SERIES

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ELECTRIC LIGHT INSTALLATIONS.

VOLUME II.

APPARATUS.

[*frontispiece* No. 1.

No. 2.

ELECTRIC LIGHT INSTALLATIONS.

VOLUME II.

APPARATUS.

A Practical Handbook

BY

SIR DAVID SALOMONS, BART., M.A.,

VICE-PRESIDENT OF THE INSTITUTION OF ELECTRICAL ENGINEERS.
ASSOCIATE OF THE INSTITUTION OF CIVIL ENGINEERS.
MEMBER OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
MEMBRE DE LA SOCIÉTÉ INTERNATIONALE DES ÉLECTRICIENS.
MEMBER OF THE PHYSICAL SOCIETY OF LONDON.
FELLOW OF THE ROYAL ASTRONOMICAL SOCIETY.
FELLOW OF THE CHEMICAL SOCIETY.
ETC., ETC., ETC.

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EXPLANATORY.

As it is always desirable that a reader should be made acquainted with the plan upon which a book is written, a short explanation may here be offered. Volume I. was confined entirely to the treatment of accumulators, but since Volume III. depends, in some degree, upon the present book, the connection between the two should be clearly shown. Volume II. relates to apparatus, and a certain amount of information is given regarding their mode of use, though occasional observations occur which are not restricted within that limit. Volume III. more particularly deals with the method of working, so that the detailed information, which some might naturally look for in this book, will be found in the one that follows. In brief, the general description of a piece of apparatus appears in this volume, and any special application of it in Volume III., the assumption frequently being that the reader possesses the apparatus.

It might appear, at first sight, as if the author were prejudiced in favour of certain manufacturers. That, however, would be a misapprehension ; for all he has

done is simply to select the foremost types, which admits of the fact that other makers construct similar apparatus, probably as good as the instruments illustrated in this work. But since all the types are comprised in those he has described, the writer felt that to have included representations of the products of every known manufacturer would have made the book merely a general illustrated catalogue; which is very far from his intention.

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INSTALLATION.

CHAPTER I.

ENGINES.

THE first consideration is the prime motor, which may be worked by steam, gas, hot air, water, petroleum, or wind. For installations up to twenty-five or thirty lamps a hot-air engine may be used, but even in such cases by far the larger number are worked by gas-engines, on account of the simplicity of the latter and the small amount of attention they require. Besides, no boiler is necessary, there is no extra insurance to pay, and no risk of any kind encountered. The "Domestic, or Davey Motor," is good in some instances. Where water-power can be obtained all the year round, and for no payment, it is the cheapest power of all. Wind is not sufficiently reliable, and even if a small mill were to be employed to charge an accumulator, the installation would have to be on an enormous scale in order to get a constant supply of current, because periods of calm are frequent. The interest and sinking fund on the increased capital, which would be required in a wind-driven installation, would far exceed the cost of the fuel in an installation of the same size, had coal or gas been

used to produce the current. Attention will be chiefly confined to gas- and steam-engines, because these are the most common motors in use. For large installations steam has so far proved the best, because till recently gas-engines, except those of moderate power, have not been so satisfactory nor so reliable as steam-engines. But now great improvements have been, and are being, made.

Until lately the gas-engine industry was much hampered by patents which rendered their manufacture practically a monopoly, the result being, as generally happens under such conditions, that all advance is arrested. The monopoly having now come to an end, great improvements have been made in the gas-engine. Messrs. Crossley have been the owners of the chief gas-engine patents, and in consequence of their long experience they still hold the first position for their engines. Lately, this firm has made considerable changes in the build of their gas-engines, with a view to render them more efficient. They have adopted the tube igniter, with certain other additions, which makes it possible to place the same confidence in the gas-engine as in the steam-engine. They have also succeeded in constructing gas-engines of considerably increased power. The price has been much reduced.

For domestic work, a 9 nominal horse-power gas-engine is the largest engine usually required.

Gas-engines will be first considered. In Messrs. Crossley's engines (worked on Otto's principle), the indicated horse-power is about double that of the nominal. Approximately, 20 per cent. of the indicated horse-power is absorbed in working the engine. The useful or brake horse-power should not, therefore, be reckoned above 80 per cent. of the indicated horse-

power. But it must be remembered that gas-engines give off, from time to time, very variable powers, depending upon the condition of the exhaust valve, temperature of the cylinder, quality of the gas, gas pressure, and other causes. It is, therefore, safe to expect, on an average, not more than one and a half times the nominal horse-power for useful daily work. In estimating the power, the makers assume that the gas employed is about 17 candles. With gas of higher candle-power, considerably more work can be got out of the engine; and it may be mentioned that the diminution of horse-power in any given engine will be less between 17- and 14-candle power gas than between 20- and 17-candle power. There are very few places in England where gas is given of a higher illuminating quality than 18-candle power, and probably in no district is it worse than 14. In some towns in the North of England, and in Scotland, the gas has an illuminating power of 27. The candle power of the gas, and its heating properties, do not always have a direct relation to one another.

The smallest Otto engine (excluding toys) is the half horse-power nominal, which gives a large indicated horse-power for its size; and 1 horse-power may be regarded as its useful power. After the 1 horse-power nominal which is advantageous for its size, all others may be taken on the average as giving a brake horse-power of one and a half times the nominal horse-power of the engine.

The method of working a gas-engine, whoever may be the maker or whatever its type, will not here be described, because clear and simple instructions are sent out with each engine. However, a few suggestions

may be made to show how, with certain modifications, any engine may be adapted for the special requirements of electric lighting. The following remarks will apply to the Crossley engine, though they are applicable almost word for word equally to other types.

Gas-engines are liable to stoppage, but this defect may, with proper precautions, be reduced to a minimum. Extra large oil- or grease-cups should be put on all bearings and moving parts. Every place where oil is generally dropped in from time to time should have automatic grease- or oil-cups. In short, the engine on being started ought to carry sufficient oil for a twenty-four hours' run, even though not more than eight hours is likely to be required. For the crank, oil is recommended in preference to grease. There is no better oil-cup made than the "Crosby." It is sight-feed, and can be adjusted to lubricate at any desired rate, and the adjustment once made, no further attention is needed. In order to create or stop the flow of oil it is only necessary to lift, or depress, a small lever. These cups are extensively used at the present day, and they may be considered to have replaced grease-cups in almost every case, in consequence of the great difficulty in obtaining two samples of grease possessing the same characteristics. The circulating water-tank, when employed, should be extra large. To avoid the danger of the slide, when this exists, sticking or "cutting up," the springs, or other arrangements in use on the slide cover, should be as free as possible. The chance of the slide light blowing out is thereby increased. Therefore, an additional protected burner should be placed in such a manner as to relight the slide light in case of such an accident. A long fine jet answers the best, because the actual source of the

flame may be six inches away from the slide, and out of danger from any puff which may come from it.

In many gas-engines the slide-cover springs are replaced by a small apparatus worked at the moments of gas compression in the cylinder, such apparatus pressing the cover up against the slide; consequently, the slide works freely, except at those times when the gases in the cylinder are ignited, and then the cover presses tightly against the slide itself, keeping all the faces gas-tight.

In the improved types of Crossley's gas-engine, this slide and slide light are dispensed with, except in the very smallest size of engines. Thus the greatest trouble attending a gas-engine is removed. A small and simple valve is substituted, which at proper times establishes a communication between the cylinder and the inside of a red-hot metal tube, kept at this high temperature by means of a Bunsen flame, which is outside the tube, and consequently quite out of reach of the gases within the cylinder. The whole ignition apparatus is termed the "tube igniter." In the Atkinson engine there is no valve, but the gas mixture reaches the heated part of the tube only when compressed in the cylinder. The ignition tube itself burns away, and till recently it had to be replaced every thirty hours. But there is now manufactured an improved metal tube, which lasts some months. These renewals cost but a few pence, and, considering the security they give against a breakdown, they would be cheap at even a higher price. If a tube be left in too long, and bursts in consequence, no harm whatever is done; the engine merely stops, and the gas taps should at once be turned off. A porcelain tube has appeared and it has been recommended, Mr. Wellington being the patentee.

In the new forms, the worm-wheel gearing has taken the place of the bevel-wheel gearing, thus removing the main source of noise in these gas-engines. The governor is made much more sensitive, the mechanism is simpler in construction, and the tendency to "hunt" eliminated. The setting of the valves to start the engine is far more convenient and practical, and all moving parts likely to be dangerous are well protected by cast-iron covers. Improvements have been made in many other details. The chief omission, as regards safety to the attendant, appears to be that of a suitable guard on the frame at the crank end to prevent the possibility of the foot coming within reach of the crank, there being a great temptation to do this when starting the engine, and many serious accidents have arisen in consequence. It is, therefore, strongly recommended to the owners of these engines that they should fix such guards at the first opportunity. Fig. 1 shows the improved form of the Otto gas-engine.

Some makers use an electric spark to ignite the gas in the cylinder. This method is not new, but, owing to the removal of many old difficulties, it has recently met with some success. The leading advantages of this plan are a saving of gas for the slide light and the absence of gas fumes in the room where the engine is placed.

It may be pointed out that all gas-engines having an ignition tube contain four valves, viz.: (1) an air inlet, (2) a gas inlet, (3) the ignition (sometimes absent), and (4) the exhaust. (In some engines there is no valve at this opening.) In those engines which have the slide the first three valves are combined in this slide simply as openings, which are covered and uncovered in succession on the same principle as the slide valve of a

steam-engine. This explains why a slide is still so much used in very small engines, there being insufficient room for the three separate valves, which the slide replaces, without undue cramping.

For want of proper attention to certain details many drawbacks commonly exist in regard to a gas-engine which are not possessed by its rival the steam-engine.

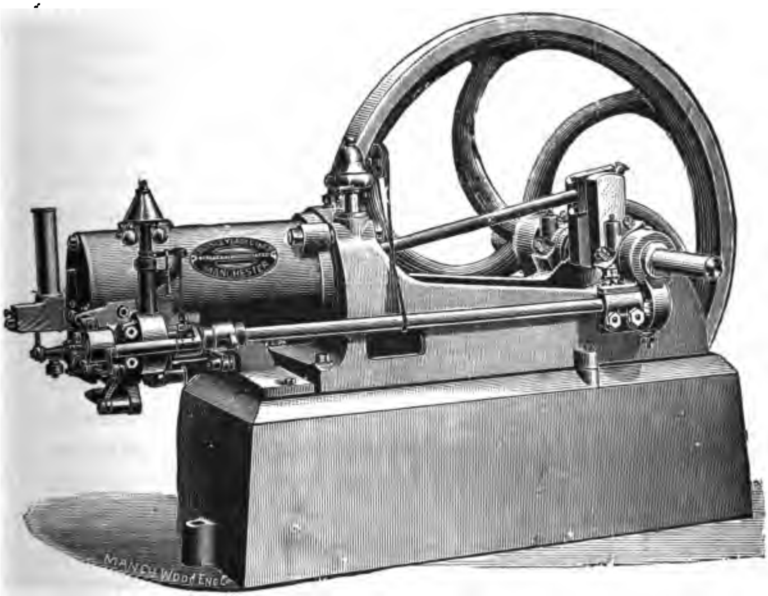

Fig. 1.—Crossley's Otto Gas-Engine.

The human race is peculiar in one respect: if one machine be so constructed as to require less attention than another, or if a piece of apparatus be made to work in some way to save labour, the conclusion is at once arrived at that no attention whatever is needed; the result being that a large number of persons are averse

to all improvements which economise labour, and progress is, in consequence, much impeded. With a view to point out more clearly what is meant, a case may be given that is of constant occurrence. A man who has attended to a steam-engine, having to stoke the boiler furnace from three to four times an hour, and to watch the gauges as well as the engine bearings, considers it almost too much trouble, when his steam-engine is replaced by a gas-engine, to see once in two hours if everything is running properly. Again, where no automatic apparatus exists, two switches in connection with the battery circuit have to be shifted each time the engine is started and stopped; and this must be done many times a day if the man in charge pulls up for his meals. Everyone knows that, under these conditions, occasions will arise when the moving of the switch is forgotten; this oversight generally results in a fuse going, or injury to, or breakage of, all the lamps that may be alight in the house at the time. Sometimes more serious damage ensues. Even if an automatic switch replaces the hand method and fails once in every four years (such an instance is known to the writer), it is held that the hand arrangements are far superior.

It must also be remembered that, if the automatic apparatus fails when charging is started, no harm whatever accrues; and, should it fail on stopping, the result simply is that the dynamo begins to run as a motor, which the attendant observes almost immediately, and he thereupon moves the automatic switch by hand. Notwithstanding all that is evidently in favour of the self-acting arrangements, yet complaint will be made if they fail once in a way. Devices of this kind will be condemned and all praise bestowed upon the hand arrangements.

The reader may be left to draw his own conclusion. In short, the present age may be described as one in which the less a man has to do the less he is disposed to do, and the greater must be his pay.

In order to assist users of gas-engines to overcome some of the smaller difficulties, which some persons encounter, the following remarks may prove of service.

Generally, when applying a match to the tube-igniter burner, the gas persists in lighting at the base of the tube instead of at the end of it inside the chimney. If this is not observed and at once rectified (apart from the fact that the ignition tube cannot be made hot enough to fulfil its duty), the Bunsen tube, becoming hot, cannot possibly be lit the proper way, unless sufficient time elapse to allow the tube to cool. The simplest way to make sure of starting the burner properly is to place the fingers over two or three holes at the base of the tube, and to hold a match over the top of the iron chimney which contains the ignition tube. When the burner is alight, the draught in the Bunsen tube now being created in the right direction, the fingers may be removed without fear of the flame travelling back to the base of the burner, which will only occur with too low a pressure.

Crossley's latest type of Otto engine would be much improved if the cam shaft had a third bearing placed near the cams. This would prevent the bending of the shaft, each time the exhaust valve is opened. The makers maintain that this bending is of no consequence; but, from a common-sense point of view, the bending is evidently wrong, since it must produce increased wear and tear, even if no further evil results arise. The possessor of any engine having such a defect can put this additional

bearing at a very small cost, and this may be done by a man requiring no special engineering knowledge—*i.e.* by a good ordinary fitter.

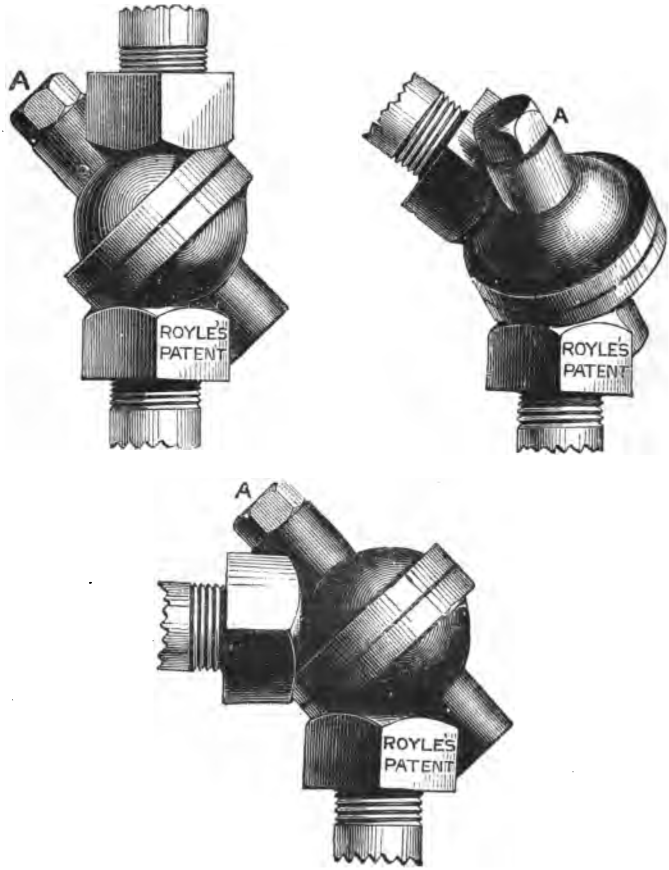

Fig. 2.—Royle's Joint.

In order to bring the gas-pipes to the engine, it is generally necessary to make bends in them. To clean

the valves, the gas-pipes have to be detached. When these are straight their removal is not easy, but the presence of bends increases the difficulty. The inconvenience thus occasioned is completely obviated by employing a Royle's joint, and in some cases it will be found desirable to have two such joints in the course of a gas-pipe. Each joint consists of a sphere cut in two halves, and if it be imagined that the gas passes in and out through its poles, the plane where the hemispheres unite is placed at an angle of 45 degrees with the equatorial plane. One bolt (A in figure) holds the two halves together, and forms the polar axis in respect to the plane of division. It will thus be observed that, if pipes are screwed into the gas openings of this joint and one hemisphere is revolved upon the other, the bolt acting as an axis or pivot, these pipes may be placed at any angle between a right angle and the straight line. This joint is, therefore, most convenient to replace all angles, bends, and "connections" (in straight pipes) at those places where the pipes require to be taken apart in order to clean the valves of the engine, since by removing the bolt from each of two such joints a length of pipe can immediately be taken away without the usual forcing and straining; and in the case of the portion of pipe attached to the engine itself, it will only be necessary to undo one such joint. In practice the author has found Royle's joint of the greatest service, saving both time and expense. This joint is illustrated in Fig. 2 in three positions.

It is usual to place the main gas tap on the side of the meter, away from the gas-engine; and this is right when the gas is permanently shut off. However, should there be any leakages in the gasfittings between the engine and this tap, the meter and pipes will become

filled with gas and air, or air almost entirely, whereby much difficulty in starting the engine will be created. A better way is to have a tap at the place where the gas enters the gas-bag, and to carry the igniter gas tube off a point between this tap and the meter. The advantages gained are the following: The engine can be started very much quicker; since pure gas enters the cylinder at once, for it must be remembered that the gas-bag is emptied each time the engine is stopped: thus there is no large space to be filled with air. If the engine is stopped for a short time, the gas may be cut off from the bag, leaving the igniter Bunsen in action, so that the tube remains hot till again required.

The meter used with the gas-engine must be about double or treble the capacity of one employed under ordinary conditions in order to pass the quantity of gas consumed by the engine. If this is not done, the meter will register too high, since the gas-engine has a tendency to suck the gas through the meter in such a way as to rotate the drum faster than it should revolve, without passing the equivalent quantity of gas.

Gas-bags, as at present made, contain a valve which acts as an anti-fluctuator. This arrangement enables the gas-engine to run without causing gaslights (in use at the same time) to jump; and its introduction has led to the disuse of a separate governor or of an anti-fluctuator. Although these two pieces of apparatus are one and the same in principle, there is this distinction between them, that the anti-fluctuator is more rapid in action. Of late years gas governors have been very much improved, and their importance is now generally recognised. The best class of governor possesses a compensating weight which enables it to govern cor-

rectly, notwithstanding the various positions assumed by the inverted cup in the mercury. Some governors contain no mercury or other fluid. The presence of a governor (in addition to the valve on the gas-bag) at the inlet side of the meter has three advantages, to secure which their continued use is desirable:—

1. The work, which would be done alone by the anti-fluctuator on the gas-bag, has part of its duty thrown upon the governor, with the result that the pressure in the mains is quite undisturbed.

2. A constant pressure can be maintained at the gas-engine meter, enabling the engine to be started at any time under similar conditions; and the value of this is too well known to the users of these engines to require further remark.

3. An unvarying pressure for the Bunsen flame. When two or more gas-engines are run together an extra small governor is necessary with each Bunsen burner, to be positive that all shall be kept burning.

Over the chimney of the ignition apparatus there should be placed a pipe of, say, an inch and a half, or two inches in diameter, leading into the open air or into a flue, to carry off the products of combustion. The lower end of this ventilating pipe should have a funnel placed on it in order to collect the fumes. At a point some five or six feet from this lower end a ball-and-socket joint should be inserted, as this enables the attendant, when looking after the ignition apparatus, to push the pipe on one side. If condensed water should run down this tube into the ignition apparatus, the trouble may be got over by putting in a T-piece at the point where the tube leaves the vertical towards the horizontal position, and screwing into this a piece of

pipe, say a foot long, with a tap at the end to draw off the water. The funnel just mentioned may have at one point a small piece of metal projecting from it like a tooth, its object being that at any time the ventilating tube may be moved to one side, and so kept by this tooth resting against the chimney of the ignition apparatus. When this is not required, it will simply be necessary to turn the funnel round. Since the ventilating pipe becomes very hot, but not dangerously so, near the ignition apparatus, a piece of wood, or asbestos, may be placed around it, so that the attendant shall not burn his hand. With this ventilating device it occasionally happens that a down-draught will blow the light out. Therefore, it is desirable to make the outlet more or less horizontally in such a direction as not to face prevailing winds, which in this country are south-west and eastwards. The north is consequently the best direction. Frequently it happens that this proposal cannot be carried out, and even when it is possible, surrounding circumstances divert the direction of the wind near the outlet. The best way under such conditions is to carry the end of the pipe up vertically and to place a revolving hood over it, such as are seen very commonly on chimneys. These hoods always turn their openings away from the wind, and consequently prevent a down-draught. Sometimes, whatever may be the conditions, down-draughts cannot be avoided. Even in such cases however, a remedy offers itself in the form of a self-closing mica valve such as is commonly employed in connection with drain ventilators. The valve will remain open as long as the draught is in the right direction, and otherwise it will close. In this way puffs of wind, which would extinguish the light, are arrested.

It will be found that, when such a ventilating apparatus does not exist, the atmosphere in the engine-room is painfully disagreeable, it may even be said to be poisonous; and these fumes will attack any brasswork that may be present. But for these facts, such stress would not be laid on the necessity of a ventilating pipe.

With large engines the air-suction pipe is laid to a point outside the engine-house and opens horizontally to keep out the rain. Over the entrance it is desirable to place a wire cage, in order to keep out birds and other animals and to prevent their placing materials in the pipe. This is the most primitive way.

Each time air is drawn through this pipe a considerable noise is created, which may in a measure be prevented by adopting the following treatment. Place, in an upright position in the ground, a glazed stoneware drain-pipe, with its socket upwards, for a depth of, say, eighteen inches, a piece of slate or stone being put under it; the bottom should, if possible, be drained, in order to prevent water collecting. In the socket insert another similar pipe. Within these pipes continue the air-suction pipe to within three or four inches of the bottom, open end downwards. This arrangement acts well as a quieter. It is further desirable to protect the open portion of the drain-pipe by a gauze netting or by perforated zinc, and by a hood of metal or of wood; the first to keep out foreign matter, and the second to exclude wet.

Another method of quieting is to carry the pipe into a short brick chimney about eight feet high, the top being covered over with a stone and a hole rather larger than a section of the air-pipe (protected with gauze) made at the side near the top. Any quieting device

beyond the air-expansion box, supplied by the makers, must not be employed, since it will affect the working of the engine. The air suction has a great attraction for boys, and it should, therefore, be placed beyond their reach. A story is told of a gas-engine that refused to work, because, as examination showed, the caps of thirteen boys had found their way into the air-pipe. One of the lads at a school, having discovered what appeared to him wonderful suction properties at the end of this pipe, began to experiment by placing his cap over the end ; and its immediate disappearance led to twelve other boys following his example.

The chief difficulty with a gas-engine is to find a method for quieting the exhaust. With engines up to 6 horse-power nominal there is not much difficulty, but for larger sizes the trouble is so great that most engineers are content to consider the exhaust silent when to ordinary ears the sound of the exhaust would be considered little short of a series of small explosions. To cure the defect, numberless devices have been brought out, such as the following :—

1. Justice's Silencer. This consists of a cast-iron bell filled with small sea-beach, a wire netting or a perforated metal sheet being placed over the mouth of the bell to keep the pebbles from falling out ; the exhaust pipe enters at the opposite end. Such an apparatus is successful on small engines, but the beach should occasionally be replaced, as the interstices between the stones by degrees become choked up, and the back pressure, which must arise in consequence, diminishes the power of the engine.

2. German quieters. These consist of cast-iron chambers, subdivided within in such a manner as to enable

the exhaust gases to expand gradually before reaching the air. When one quieter is found to be insufficient, more may be added until the desired effect has been produced, the gases passing through these successively. The apparatus answers very fairly, but it is expensive.

3. Exhaust pits. The end of the exhaust pipe, in this case, must have attached to it an arrangement to prevent the material contained in the pit from entering the pipe. Usually a cast-iron box, with holes pierced in it, except on the upper side, and standing on feet, is bolted to the end of the pipe. This box is called a "pig," from its resemblance in shape to that animal. The material placed in these pits is frequently coke, broken very small. This is not a desirable substance, because it is so soon converted into powder. Flint sea-beach, such as is found on chalky coasts, is far preferable. The pit may be made in one of two ways: the exhaust may enter at the bottom, so that the gases rise to the top, where they are led off into the air by a small flue; or the pit may be left uncovered. In the second method the pit may be constructed near the surface of the ground like a trench, the exhaust pipe entering at the bottom at one end. In this case heavy flagstones should be placed over it, the further extremity being left open or in connection with a flue. The beach should be deposited in these pits in a graduated manner, the stones becoming smaller as the distance from the exhaust pipe is increased.

Under no conditions must the exhaust pipe be taken into a drain or a flue, for a serious explosion may one day result; because, should the gases in the engine cylinder fail to ignite, the explosive mixture would escape by the exhaust, possibly to be ignited by

the next discharge of burned gases. Each engine should have a separate exhaust pit.

The principle of quieting the exhaust depends simply upon expanding the gases gradually before the latter reach the atmosphere. The exhaust gases leave the cylinder under considerable pressure, and, when they are brought to the air direct, the expansion is so sudden as to create a loud report; but when their volume is gradually increased by passing through the devices just described, approximate silence can be secured. Boyes and Cunningham's Centrifugal Steam Separator acts as a quieter, and on small engines they are decidedly successful; but the writer, not having seen them in use upon large engines, cannot express an opinion as to how far they answer in these cases. Much economy could be secured by letting the exhausted gases leave the engine at a lower pressure.

Recently the author has erected two 14 nominal horse-power gas-engines, and has succeeded in completely quieting the exhaust by the use of the trench form of pit. A description of one of these pits may be useful. The exhaust pipe, with a pig attached, enters at the bottom of the trench, and at such a point that half lies on either side of the pig. The trench is 3 feet deep, 2 feet 6 inches wide, and about 23 feet long. The bottom is concreted and drained, and the sides are of brick. The top is covered with York flagstones 3 inches thick, and above this 6 or 7 inches of earth. The gases reach the open air through two brick flues, about 5 feet high, and a clear section of 8 inches by 4 inches, one of the flues being placed at either end. The openings are covered in such a manner as to prevent the rain from entering. The stones, which are placed where the exhaust enters,

are about the size of a fist. The remainder of the space is filled up with beach of five gradations, smaller and smaller as the ends of the pit are approached, the last size of pebbles being known as "pea-beach." This graduated arrangement is also carried from the bottom up to within 6 inches of the top of the pits. The rest of the space is taken up with pea-beach through the whole length, but an interval of, say, ½ inch is left between the flagstones and the contents of the pit, in order to prevent the possibility of shock being conveyed to the former. This arrangement has proved thoroughly satisfactory, also cheaper and better than the other methods mentioned, while the quieting results are extraordinary. When space is not available, vertical pits must be resorted to.

When the Otto engine is making an explosion as often as it can, a single "miss" will probably cause the engine to stop, especially in the larger sizes of this engine, for the gas-valve cams will pass one another in such a way that they no longer come into action. When these engines are used for electric lighting, since they usually work near the maximum load, the stoppages are a common source of complaint. An inconvenience of this kind can be entirely overcome by the addition of any arrangement which shall prevent the roller cam, actuated by the governor, passing the point where it will miss the projection on the cam shaft. This addition must be removable, or must slide aside; otherwise, when the engine has a starting lever, it will be found that the action of this gear cannot come into play when required. Only one danger exists in the employment of this convenient arrangement. It is that, should the engine by any chance stop with the gas cams in action,

and consequently the valves open, gas will enter the cylinder and pass out by the air suction, whereby gas escapes into the room when the air is not drawn from the outside. Unless this leakage be immediately discovered, an explosion will undoubtedly occur through the presence of the ignition burner. Such accidents have frequently taken place.

In the smaller sizes of engines the possibility of a miss explosion pulling up the engine, when the latter is working under a heavy load, does not exist, owing to the peculiar construction of the governor in these types. Also in these small engines the air inlet is situated below the cylinder, and consequently the engine draws its air supply from the room. It is, therefore, evident that with a small engine the danger mentioned is always present, unless the precautions now to be recommended are acted upon, viz.:—

Use that arrangement, by means of which the least risk of stoppage can be secured.

All sizes of engines should draw the air supply from the outside, so that, if by chance the combination mentioned should arise, the gas will simply escape into the open air and do no harm.

On stopping, it should be seen that all cams are free; thus preventing unnecessary strain to springs and ensuring the closing of all valves, the gas being completely cut off, although the taps may have been left on, and securing the cylinder from rust by moisture entering through the exhaust or air suctions.

In Messrs. Crossley's instructions, sent out with their gas-engines, it is specially stated that the ignition valve must have a given length of stroke; and that, should this stroke be decreased through any parts wearing, the

consequences may be dangerous. The danger consists in the possibility of the gases within the cylinder being ignited at a wrong moment, thereby causing the engine to run the reverse way; which would very likely result in an accident to the man starting the engine. Particular attention should, therefore, be given to this point. When the engine is started by the dynamo or a motor, this danger is eliminated. It may also be mentioned that, by carefully adjusting the ignition valve, it is possible to start the engine with far greater ease than when this is not the case. In those engines where the ignition valve is absent, great care has to be taken to adjust the Bunsen flame to heat the ignition tube at the right place; adjustments existing for this purpose.

A clutch on the gas-engine crank shaft possesses an advantage which cannot be overrated; it enables the engine to be started without the other machinery, and when the engine is in motion the clutch is put in action. To effect this purpose, Messrs. Crossley supply a clutch with their engines, but it cannot be released while the engine is in motion. In most cases this is a drawback, and therefore it is recommended that, whenever a clutch is employed, it should be one of such a type that it can be thrown in and out at any time. Since the clutch on a gas-engine has to withstand the force of the explosions in the cylinder, it must be of larger size than would be required had it been placed upon a steam-engine of equivalent power, as the sudden thrusts would cause slipping at such times; which, in some instances, would not be desirable.

The current produced by a gas-engine may be rendered completely steady, if the clutch is used, by not tightening it up too much, and thereby allowing a slight

slip at the moment of explosion. There is no loss of power in adopting this proceeding, since what might to many appear as a loss is really stored up in the fly-wheels. The only consideration required is that the clutch should be of a kind to permit of this being done without injury to the apparatus. This method has been adopted in the installation at Broomhill; the current is quite as steady or steadier than when steam-engines of the best construction were in use, and all the heavy fly-wheels commonly attached to dynamos are entirely dispensed with.

Of all the clutches in the market the simplest and best is probably that constructed by the well-known firm of Messrs. Mather & Platt. Fig. 3 shows the arrangement.

A is the boss which carries the pulley and runs free upon the shaft. B indicates two halves of metal, which can be made to pinch the boss by being approached to one another by means of right- and left-hand screws actuated by the levers C C, when the collar D is advanced towards the boss. D can move along the shaft, but must revolve with it. This collar is moved to and fro by any suitable piece of apparatus. The clutch is strong and is satisfactory in all respects.

When using a clutch on a gas-engine, two points, generally neglected, require special attention.

1. The necessity of putting the clutch on gradually, so that the load shall not be suddenly applied. This method has no mechanical drawbacks, and avoids a "swing" being given to the belts, which is accompanied by slipping. The swing is reflected on the lamps.

2. The tightening up of the clutch should be effected by the application of a force at right angles to

the axis of its shaft. This avoids, first, the fly-wheel, pulley, or collars upon the crank shaft jamming against the bearings, and thus producing increased friction at the least desirable moment; secondly, the application of force in a direction unsafe for the attendant, for, should he slip, he might become entangled in the pulley.

The author employs worm-wheel gear for putting the

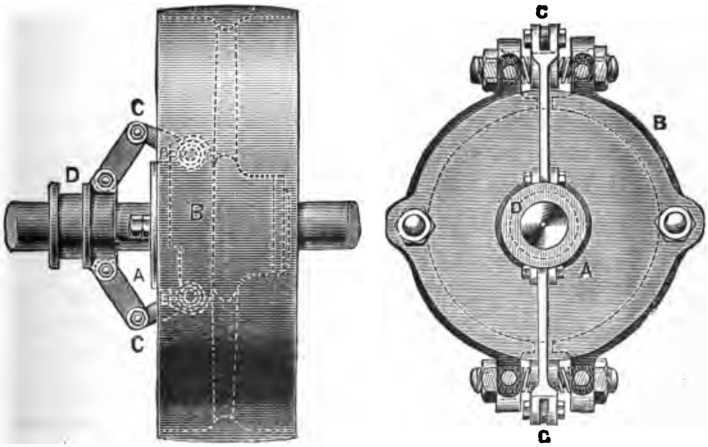

Fig. 3.—Mather Platt's Clutch and Pulley.

clutch in and out, which eliminates all personal danger and possibility of the clutch itself being thrown out by the vibration of the engine.

The makers of gas-engines have frequently been found fault with, because it appears as if the crank shaft bearings are untrue or the shaft is too weak. The ends of the shaft appear to "wobble," this motion being reflected upon the pulleys. As a matter of fact, it is impossible to prevent this circumstance; the suddenness with which

the force is applied to the crank causes the shaft to bend slightly each time the gases are ignited in the cylinder. This want of truth in running is in no way due to bad construction. The cure lies in a total reconstruction of the engine.

Intending users, as well as possessors, of gas-engines are often anxious to know how much power is absorbed in the engine; and although this subject has already been referred to, it is, perhaps, desirable to repeat the information, but in more detail. The makers of all gas-engines give the nominal and the indicated horse-power of each size, neither of which is of any practical value to the user, unless he knows what the brake horse-power is; this value being the difference between the indicated horse-power and the power absorbed by the engine to run itself without a load. Knowledge of the usable power is of the highest importance, for supposing an engine styled "2 nominal horse-power," and stated as giving "4 indicated horse-power," requires 3 indicated horse-power to run it when doing no work, there will remain only 1 brake horse-power. If, however, to run this engine free 1 indicated horse-power be required, the usable power would be 3 horse-power. Hence the purchaser of an engine must not be misled by a maker's statement of the high indicated horse-power of any particular engine, as this will not of necessity indicate the brake horse-power. It is surprising that gas-engine makers do not give the brake horse-power in addition to the information usually supplied.

The gas-engines made by the best firms usually absorb about 20 per cent. of the maximum indicated horse-power to run them free, so that the brake horse-power may be taken at four-fifths of the stated indicated horse-

power. When an engine has been running for some little time, a slightly worse result must be expected, in consequence of the exhaust valve becoming dirty; and not more brake horse-power than one and a half times the nominal will be the result.

The majority of the valves in gas-engines are known as of the "mushroom" type. If to these were given a slight rotation during the whole period in which they are working, it would assist materially to keep them clean and true. Very simple devices could be employed to effect this end. In the best forms of water rams, where it is of great importance that the main valve seatings shall remain true, this revolving principle is adopted with great success.

Governors do not, in regard to gas-engines, regulate with the same precision as the same apparatus does with the steam-engine. It is generally a case of letting in or cutting off the gas altogether. The Otto engine and those built after this type, as well as some others, have a kind of intermediate regulation whereby the governor admits more or less gas, as required, but only in definite given proportions of the maximum. In this way very fair regulation is obtained, provided heavy fly-wheels are employed.

Great care should be taken in frosty weather to empty the water-jacket around the cylinder. If this is not done, the water, freezing, bursts the jacket. When an engine is placed in a situation where it is likely to be exposed to very low temperatures, one of the following courses should be adopted to prevent such an accident:—

1. The simplest, as well as the most reliable, plan is to place an ordinary gas burner near the cylinder and

keep it alight all through the winter. If this burner uses 5 feet an hour, and gas costs 3*s.* per 1,000 cubic feet, the expense will not exceed 4*d.* a day, 10*s.* a month, or for the whole winter 2*l.* This outlay may be regarded in the light of an insurance premium not only upon the gas-engine, but for the cells, if present, also; because the latter would clearly suffer in the event of a breakdown extending over a long period. The expenditure is also a guarantee for an uninterrupted supply of current to the house.

2. An electric thermometer may be used to ring a bell at any desired spot when the temperature approaches freezing-point. Notice being thus given, the attendant must draw off the water from the cylinder jacket.

3. An electric thermometer may be employed, as a relay, to empty the water-jacket automatically.

4. Throughout the winter months the water-jacket may be emptied every time the engine is stopped.

Of all the above methods, the first is by far the best, because it is independent of personal attendance and avoids the expense of automatic devices. The fourth plan, however, appears to be the simplest, but it is accompanied with a disadvantage, viz. that, if it be forgotten at any time to turn the water on when starting the engine, considerable injury may result to the cylinder.

If the cylinder should become too hot, in consequence of the failure of the water circulation or from any other cause, the engine will give off far less power and the cylinder may become damaged. It is important, therefore, to keep the temperature of the circulating water as low as possible, say not above 100° F., although 150° F. is allowable.

It is better to start a gas-engine in the ordinary way, or, still better, with an electric motor, than to have a "self-starter," which in some types is a dangerous piece of apparatus. There are in existence self-starters that are not dangerous, but how far they are of service in practice is matter of question. In most cases they depend on passing into the cylinder a ready mixed explosive charge by means of a special apparatus, and then igniting the mixed gases, the crank having been placed in the position most favourable for starting. In order that the first proposition may be successfully carried out, it is essential that everything should be quite air-tight; and here lies the difficulty in practice. No doubt a considerable jar is given to the machinery when the explosion takes place, since the engine is standing.

In small installations, where accumulators are present, a clutch on the gas-engine is of no importance, and the dynamo may be employed as a motor to start the engine, as will be explained later on.

The resistance of the armatures of large dynamos is very low, so that the starting of such a machine, as a motor, is virtually short-circuiting the cells. Again, the magnets being large, time is required to magnetise, often as long as three or four minutes, but rarely less than half a minute; and during this process an enormous current is passing through the armature. Even if the magnets were first excited, a heavy current would pass the armature, and even to use a variable resistance would not answer. If the armature of a large machine could be revolved at a high speed, and then the current turned on, no harm would be done, as a counter E.M.F. to the battery E.M.F. would be set up; but this is rarely feasible. In small dynamos the armature resistance is

greater, the field magnets excite very quickly, and the speed is more rapidly got up. Hence, large dynamos should not be used to start the engine.

When the gas-engine exceeds 8 horse-power nominal, it is very heavy work to start it by hand; and if a current from accumulators is available, the way adopted by the author in starting his gas-engine will be found of great convenience. The dynamos employed with engines of 8 horse-power and upwards are too large to act as motors for starting purposes, because they would probably require more current to set them going than would be good for the plates in the battery; and, since an engine of 14 horse-power can be started with a force of only 1 horse-power, it is evidently more economical to use a small motor for this purpose only.

The method employed for starting the two 14 horse-power nominal gas-engines at Broomhill will be described, as it has proved successful in every way. (See Figs. 4 and 5.) A 1 horse motor, with a pulley 4 inches diameter, rotates a countershaft placed about 6 feet away. The motor runs, upon this countershaft, a pulley, 2 feet 6 inches diameter, by means of a 4-inch wide chain type belt; but any other kind would answer equally well. The countershaft is carried by standards 18 inches high, and these are fixed to the floor. Upon this shaft are keyed two 6-inch pulleys, each pulley being in a line with a fly-wheel upon one of the gas-engines (there being two engines). The countershaft is about 8 feet from the centre of the fly-wheel.

For the sake of simplicity the arrangement will be described in respect to one gas-engine, since the other engine is treated in the same manner. Fig. 4 is made from a photograph showing the arrangement,

A 4-inch belt is carried over the small countershaft pulley and fly-wheel. So far, it is clear that, if the motor were started, the fly-wheel must revolve ; but since, under these conditions, the load upon the motor would be too great, and probably injure it considerably, if it could even be started at all, it becomes necessary to start under a light load, that speed may be got up before the work is applied.

If, therefore, the belt around the fly-wheel could be slackened at starting, to permit slip, and then tightened, the desired result would be attained ; and this is what is actually done. The success of the starting arrangement depends upon the method employed for tightening and releasing this belt. It is evident that the lower side of the belt runs not far from the floor, whilst the upper side passes over the top of the fly-wheel. Now, the belt, instead of going direct to the top of the fly-wheel, is carried some 2 feet above it over a pulley, whose shaft is supported by an arm 2 feet long, hung by pivots at the end opposite to where the pulley shaft is. It will thus be seen that, if this arm and the pulley were free, the arrangement could be swung like a pendulum (the pulley being the weight). When the pulley arm hangs vertical, the common tangent to the pulley (which is 6 in. diameter) and fly-wheel meets the floor of the room at right angles. The belt, if it were stretched tight, would therefore touch approximately one-fourth of the circumference of the fly-wheel. The belt, instead of being put on tight, is allowed to be very loose, so that when the engine runs it is quite free. Suppose the pulley is pushed over the fly-wheel, this action evidently will raise it, for the other end of the arm is hinged at a fixed point. By this means the belt is tightened to any

desired extent; not only so, but it will now embrace nearly half the fly-wheel. Since there is a considerable strain upon it, the belt must be well jointed with strong clips or otherwise. (The pivoted countershaft is the type used with Messrs. Richard's "dimension circular saw," and these are actually employed in this instance.)

It may be useful to know of a strong flat joint very suitable where much strain is put upon a belt. To give an example: let it be supposed that a 4-inch belt has to be joined. Make the ends square and cut each in the direction of the length of the belt to a distance, say, of 2 inches, in five or six places, the leather would then appear like a series of fingers. Assuming that there are four such fingers on one end and five on the other, each finger is now twisted through a right angle, and those at one end of the belt are pushed into the fingers of the other end, so that they alternate. A hole is next pierced through all of them, and a long pin, having a head at one end, is pushed through. Upon the other end a washer is riveted. When neatly made, this joint looks like a set of links in a belt, and will bear enormous strains.

In the starting gear, two difficulties will present themselves at this stage: first, how to apply a man's power to this movable pulley, for the weight of two men is necessary to do what is required; and second, when the engine is started and the belt tension relaxed, how to prevent the wearing of the belt by the fly-wheel continually rubbing against it.

The first point is settled in this way: the pulley end of the arm has a loop, to which is attached the hook of a set of "pulley blocks." The upper block is fixed to

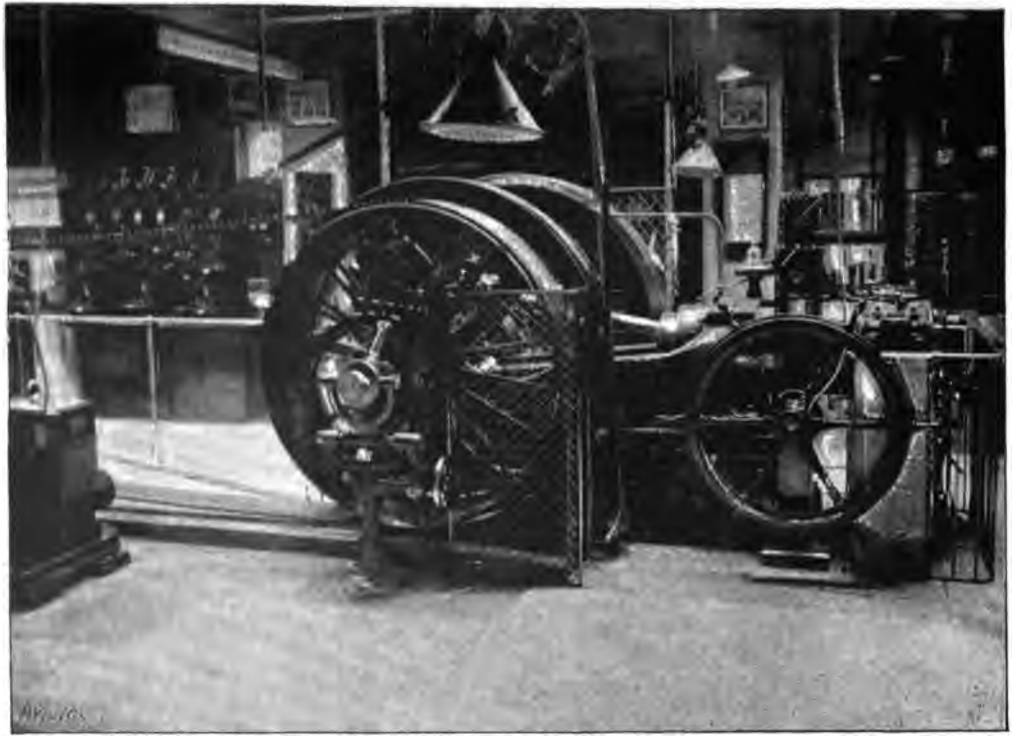

Fig. 4.—Author's Method of Starting Gas-Engine Electrically. The Clutch and Clutch-Gear can also be seen.

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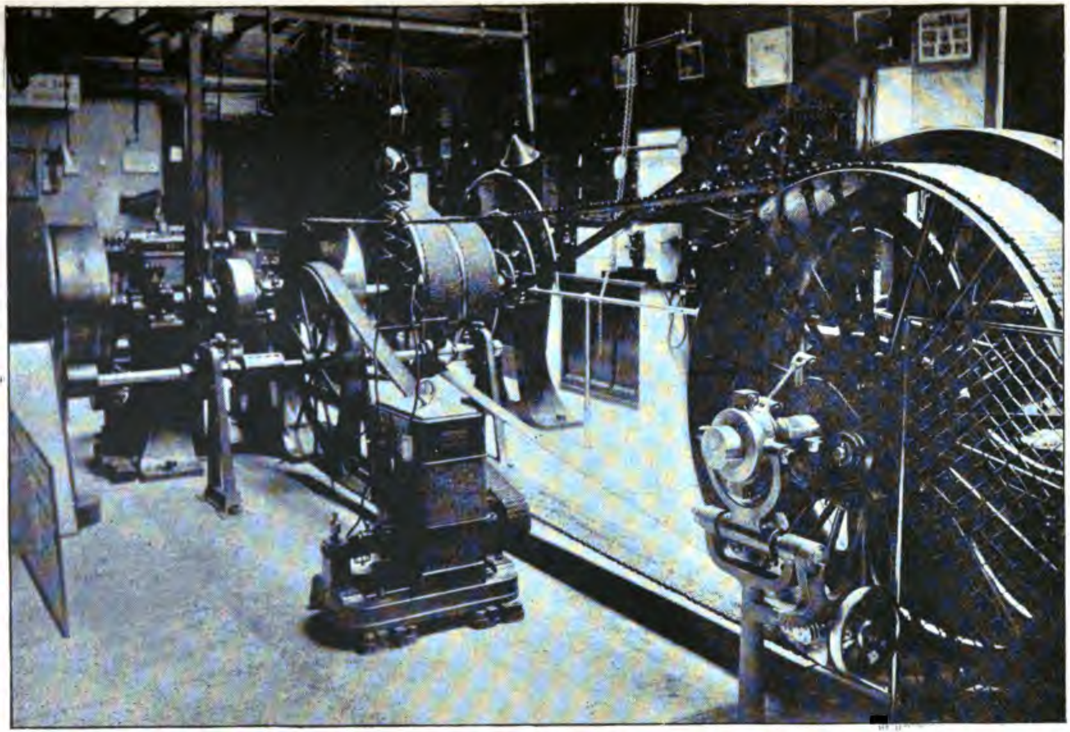


Fig. 5.—Another View of Electrical Starting Gear. The Clutch and Clutch-Gear can also be seen. [*to face p.* 30.

the roof. This latter set has two pulleys, whilst the lower block has one.

The rope to be pulled comes nearly over the centre of the fly-wheel, and consequently in an inconvenient place; a guide pulley, therefore, is fastened to the roof at a spot near the cylinder of the engine, to lead the rope to the place where a man would naturally stand when starting the engine. At this place also there is fixed a post to which is attached the motor-stepped starting-switch, the resistances used for starting the motor being placed in a convenient position out of the way. By means of these pulley blocks it will now be easy to tighten the belt sufficiently to start the engine, but as pulling a rope is not the best method, there is added the facsimile of a steering wheel, the end of the rope being fixed to the small barrel or nave, whilst the power is applied to the rim of the wheel by means of the handles. The wheel gives a further leverage of at least 3 to 1, the final result being that a child could start the 14 horse-power engine. This plan is applicable to engines of any size.

Secondly, to prevent the belt from rubbing after the engine is started, an upright bar (1 inch square in section) is fixed on the ground at one end, and attached to a roof beam at the other end, in order to make it rigid. It is so placed as to be slightly at one side of the fly-wheel and about an inch behind it. Upon this bar slides a square piece, into the two opposite sides of which pins about 6 inches long are screwed. The one over which the belt passes has a roller upon it. One side of this square sliding piece has a set screw. The upright square bar is filed round at a height nearly on a level with the top of the fly-wheel, and only long

enough to enable the sliding piece to be turned round at this place.

In using the apparatus proceed thus. Move the sliding piece up to the rounded part of the bar, one pin being used as a handle; here turn it round, so that the pins are parallel with the piston rod, and consequently free of the belt, and fix with the set screw. Start the motor gradually up to full speed, then turn the steering wheel to tighten the belt. The engine having been prepared for running, starts after a turn or two of the fly-wheel (at the rate of four or five revolutions per minute). The steering wheel is then released, when the belt will slacken itself, because the movable pulley falls by its weight till the arm is vertical or nearly so. Stop the motor, then release the set screw of the square sliding piece, turning it so that the pin carrying the pulley passes under the belt; slide it down to the bottom, when the set screw can be tightened or not as may be necessary. If the upright bar has been properly placed, it will be found that the belt is quite free of the fly-wheel.

In reading this description the operations may appear lengthy, but, inasmuch as the engine mentioned can be started in 20 seconds when hurried, and in 40 seconds with due leisure, the simplicity of this method can be realised.

To sum up: having prepared the engine for starting, run the motor and turn the steering wheel; to release the belt, when the engine is running, let go of the steering wheel, stop the motor, and slide the pin piece down; when the gas-engine is stopped, run the sliding piece up again, to be ready to start the next time. To dispense with a set screw in the sliding piece, this may be

counterpoised by means of a cord, passing over a pulley carrying a weight, as done at Broomhill. It is desirable to have a second switch for turning on and off the motor besides the step switch, so as not to wear away the contacts of the latter.

Other methods of starting an engine may be adopted; such, for instance, as permitting a motor to revolve a very small pulley, which may have a biting surface of wood, or indiarubber, suitably mounted, that it may be approached and made to press upon the rim of the fly-wheel, causing it to rotate by the friction. This plan is troublesome, and not a good one.

Many methods of starting a gas-engine by hand have been devised. Amongst them is one that resembles a rachet spanner with a very long lever, which is worked up and down like a pump-handle. This the author tried as far back as 1875, and it has appeared on more than one occasion as a new device since that date. In practice the quickest way is to turn a fly-wheel by hand. This, in the case of large engines, is laborious; but by attention to certain points much toil is saved in the process: observe that all valves upon the engine are in thoroughly good order, no leakages, so that no air may be in the gas-pipes, a constant gas pressure, and the ignition valve carefully adjusted that it may act at the proper moment, and generally pay attention to the various points already mentioned.

The tight side of the belt to the dynamo should be on the floor side, which avoids the possibility of the belt rubbing on the ground when it wears slack (this often happens when the belt is placed near the floor), and a better grip is obtained on the fly-wheel and pulley.

If no other method is available, the difficulty may be

got over by making a gas-engine run the reverse way (which can be done at a very small cost), should it be so desired.

It is not unfrequent, in order to obtain a little more steadiness with the engine in those cases, where this cannot be secured by other means, that the slack side of the belt is allowed to be on the floor side, care being taken that under no circumstances it shall rub on the ground. This mode of procedure permits a considerable slip to exist at the moments of explosion.

Special high-speed gas-engines are now made for electric lighting purposes, and they work very well. When the general form of engine can be employed it is preferable to use them.

It may interest some readers to see the kind of diagram which is obtained from a gas-engine. Fig. 6 illustrates the point.

After a definite run, predetermined upon, there are many good ways of cutting off the gas supply, electrically and mechanically; Mr. Cunynghame's home-made apparatus being one of the best. A common clock is used with a weight instead of a spring. This weight falls a certain distance per hour, and placed behind it is a scale marked in hours. The weight, on reaching the bottom of the scale, or zero-point upon it, comes into contact with a lever; the clock weight continuing to fall, and pressing upon the lever, causes it to move and to discharge a weight which turns a tap, cutting off the gas supply to the cylinder and slide light, and stopping the engine in consequence.

To put the apparatus in action, the discharging weight is set, and the clock weight is pulled up till it reaches a number on the scale corresponding to the number of

hours the engine is to run. The engine and clock are started together.

In order to avoid the recoil, which occurs with gas-

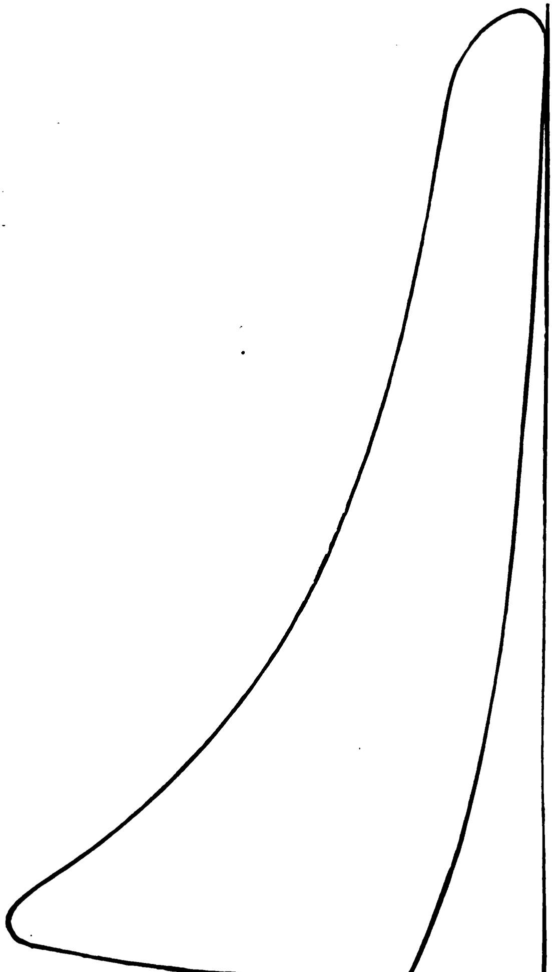


Fig. 6.—Diagram illustrating working of Crossley's "Otto" Engine, showing power developed and steady rise and fall of pressure in the cylinder.

engines on stopping, and which causes the brushes of the dynamo to be injured by the armature running the reverse way, it is desirable to have a tap fixed in the place of the screwed plug intended for the indicator, and to open the tap on turning off the gas; thus preventing the air or gases in the cylinder becoming compressed, this being the cause of recoil. The time-device could be made to carry out this additional requirement. When the engine has a clutch, the bad effect of the recoil is avoided by releasing the clutch before stopping. This relief tap is also very convenient for starting the engine, because the fly-wheel can be moved freely when the tap is open.

Fig. 7 shows the "Stockport Gas-Engine," which was made to give an impulse at every revolution. At the present time this engine has the "Otto" cycle, the same as in the Crossley Engine.

It must be remembered that, although it is usual to speak of the gas exploding in the cylinder of a gas-engine, this is by no means true. When gas and air are compressed (the mixture being such as is used in a gas-engine) and ignited, a rapid burning takes place with a development of considerable pressure; but this has no approach whatever to an explosion as ordinarily understood, the maximum pressure being about 150 pounds per square inch.

There are many other forms of gas-engines, but they can all be classed under three types:—(1) Those which give an impulse at every two revolutions, such as Crossley's Otto Engines; (2) those which give an impulse at every revolution, the gases being compressed; and (3) those which give an impulse at every revolution without the gases being compressed, as in the Bishop Engine.

Fig. 8 shows Priestman's Petroleum-Engine, which has proved very satisfactory where gas cannot be obtained, and where a motor of the gas-engine type is

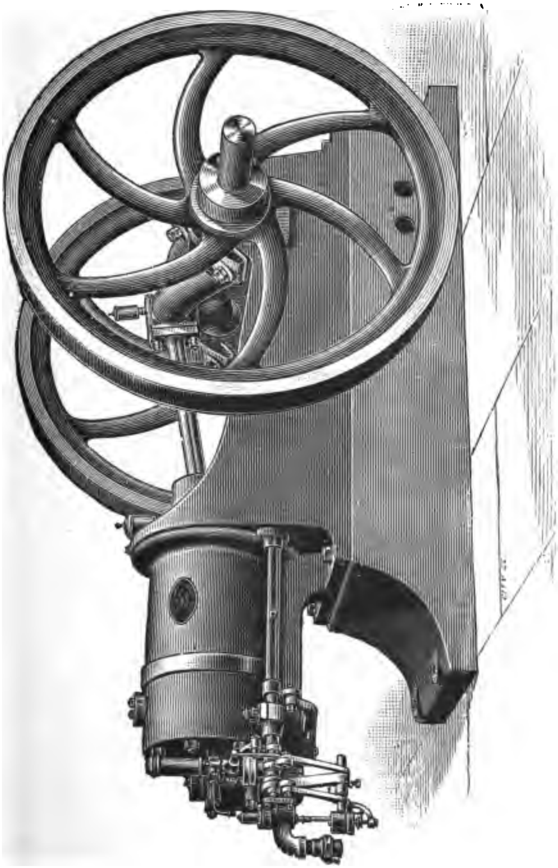


Fig. 7.—Stockport Gas-Engine.

required. In appearance as well as in action it is very similar to the gas-engine. The gases are ignited by means of an electric spark. Mr. Yarrow has been

successfully experimenting upon the possibility, in a modified common steam-engine, of using petroleum vapour instead of steam.

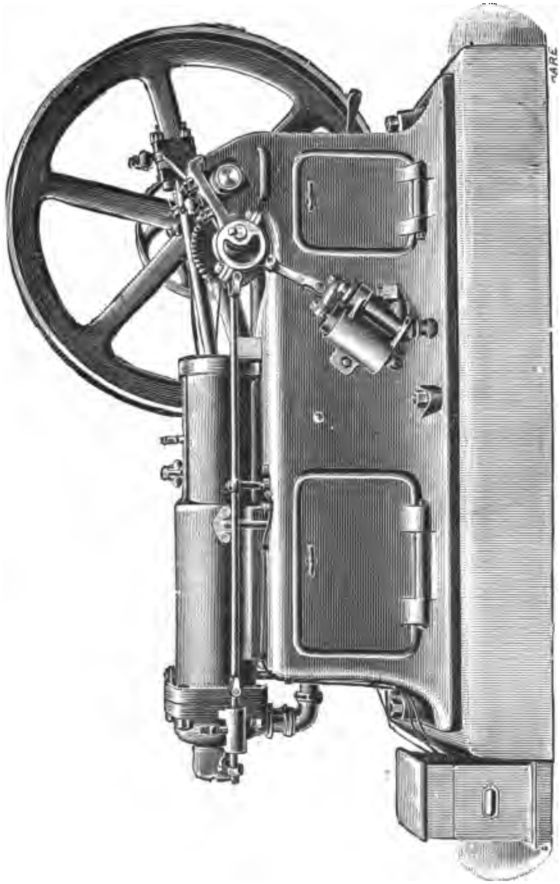


Fig. 8.—Priestman's Petroleum-Engine.

With all forms of petroleum-engines a good ventilation must exist in the room where they may be placed, and all leakage of petroleum and escape of its vapour must

be prevented. Otherwise, should a light be brought into the room, a serious explosion may occur; or this result may even be produced by the engine's ignition light, when this is employed. There are many makers of petroleum-engines.

All fly-wheels ought to be guarded.

All moving parts of the machine should be protected for personal safety, the actual details being altered to meet the peculiarities of the situation.

Turning our attention now to the steam-engine, the first point is to see that the oiling arrangements are perfect. The boiler should have two methods of being fed with water, a precaution which often prevents breakdown; and the water supply should be ample.

The heating of the feed-water is an important point. Much scaling of the boiler is avoided, straining of the boiler plates through extremes of temperature is prevented, the steam pressure is more constant, and fuel saved. When the water is very hard it may be found desirable to use a "boiler composition" or some apparatus for softening it.

Mr. Henry Crooks, C.E., brought out a new form of paint, which has an important use, and should be largely employed for all bearings, both of engines and dynamos. It is vermilion in colour, but as soon as its temperature is raised over 100° F. the colour alters, and at about 150° F. becomes dark brown. On lowering the temperature the original colour is restored, and these changes may be repeated an unlimited number of times, the properties of the pigment remaining unaltered. The paint is said to consist of a mercuric compound. For protection this paint may be varnished over without altering its qualities. For moving parts (which cannot

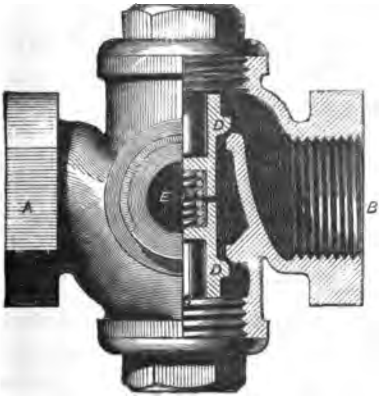
be touched, in order to observe the temperature, except at some risk) such a colour indicator is invaluable ; and it may also be used to show whether electrical conductors are overheating, since 150° C. is the highest temperature to which conductors should be allowed to rise. It is only necessary to paint a small patch on every part liable to heat. A pound of the pigment, therefore, would do the work of a dozen installations. It would appear that this paint can no longer be obtained. The author, however, gives a composition which will answer the purpose. Five parts of red mercuric oxide and one part vermilion, made up into a paint in the usual way by mixing them with oil and turpentine, will give the desired results.

In electric light installations the following additions will be found of considerable value. Everyone is aware that, unless the cylinder cocks are attended to on starting, at times during running, and on stopping, there is great risk of the cylinder ends being blown off by water collecting in the cylinders, where relief valves do not exist ; and generally these are added only on very large engines. It is also well known that water collecting in the cylinder lowers the efficiency of the engines. All danger may be avoided by the use of a very pretty little contrivance (shown in Figs. 9 and 10) consisting of a casting with three outlets, A, B and E, containing two small valves, D D, with a spring between them. Two of the outlets, A and B, are connected with the ends of the cylinder, in place of the blow-off cocks, and the third, E, is led to a drain. The screw caps, C C, shown in the diagrams, give access to the valves. The whole time the engine is running the valves work automatically, and the one connected to the end of the cylinder, under

no pressure, is opened at each stroke, thus allowing the condensed water to escape. When the engine is standing, the valves remain open, so that both ends of the cylinder are allowed to drain.

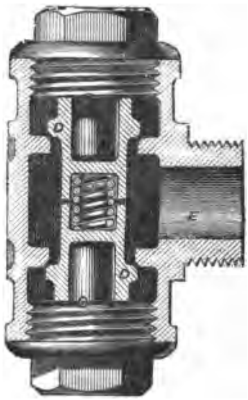
Cylinder cocks may also be added, if thought necessary. In the course of a seven years' trial there

Fig. 9.—Side Elevation.



SIDE ELEVATION
HALF IN SECTION

Fig. 10.—Cross Section half in Section.—Aquajector.



CROSS SECTION

A, B, Connection with either end of cylinder. C, Screw caps for cleaning, examining, or removing valves. D, D, The valves which allow water to escape every stroke of the engine. E, Exhaust connection. F, Spring which opens both valves whenever the engine stands.

has been no failure of the apparatus, nor has any examination been required. As far as the author is aware, this apparatus, called the Aquajector (Figs. 9 and 10), is made by only one firm, viz. Messrs. Bailey & Co., of Manchester; and the price being almost nominal, its adoption ought to be general.

There is also a very convenient form of fusible plug, introduced by Mr. Williams, one of the Boiler Insurance Company's inspectors, which dispenses with the use of

tools in testing and replacing the plug at any time Since the new fusible parts cost only *6d.* each, the expense of renewal is reduced to a minimum without sacrificing efficiency. The Boiler Insurance Companies accept these plugs, which, therefore, may be regarded as perfectly reliable.

In all installations oil is a large item of cost, especially under the slovenly and wasteful system of storing and using which is generally in vogue. By employing Richter's Economiser (see Fig. 11) a great saving is effected, and much oil may be used two or three times over by fitting a filter to the economiser. This apparatus, which consists of a reservoir and pump in a compact form, is inexpensive and soon saves its cost.

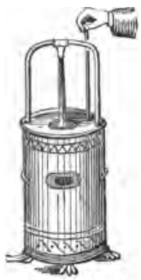


Fig. 11.—Oil Economiser.

Pans should be put at all points where oil running through bearings can be caught, and this waste oil should be placed in a separate economiser for future use, but must not be mixed with the new oil.

In speaking of these various contrivances, it is intended not to advertise the articles, but simply to indicate some valuable resources available to those who may, perhaps, for want of them, be working at great disadvantage. By an expenditure of from five to ten pounds the whole of these improved apparatus may be added to a small or to a large installation.

A self-acting sight-feed lubricator ought invariably to be attached to the cylinder. The use of tallow and fats must be avoided. All mineral oils are good, such as Engelbert's, Ragosine, Asbestoline, and the like. Special

arrangements sometimes exist whereby the lubricating of the cylinder may be dispensed with.

Grease for bearings is far more convenient than oil, and much cleaner. Grease-cups, if fairly large, require replenishing but once a month, so that the engine always stands ready to start. There are many greases in the market, and it is advisable that the user should try several samples in order to ascertain which kind will best suit the purpose intended. Experience has shown that 5*s.* worth of grease goes as far as 5*l.* worth of oil, and the friction is in no way increased by its use. At the starting, it is only necessary to adjust the grease supply for keeping the shaft cool. When this is once done, no further regulation or attention is ever required beyond refilling the cups; and their indicators show exactly the amount of grease left in them.

Occasionally it is necessary to clean the bearings and to make sure that the channels in them are clear; this is done by running a little petroleum through them, in place of oil or grease.

The author has found great difficulty in obtaining two samples of grease alike, although obtained from the same manufacturer and professing to be of the same quality. In consequence of this, he has abandoned the use of grease for his engines and dynamos, so far as regards the main bearings, but retains it for loose pulleys, motors, and general machinery; for, excepting loose pulleys, the running is not over long or continuous periods. In the case of loose pulleys, the grease is fed by means of a spring and therefore can be adjusted to the quality of the lubricant employed. Spring grease-cups would not be suitable in other instances, because the feed would be too quick.

A novel and a certain method of applying grease is that of Messrs. Thompson Bros. The grease-cylinder is shown in Fig. 12, and the method of its application to an engine in Fig. 13.

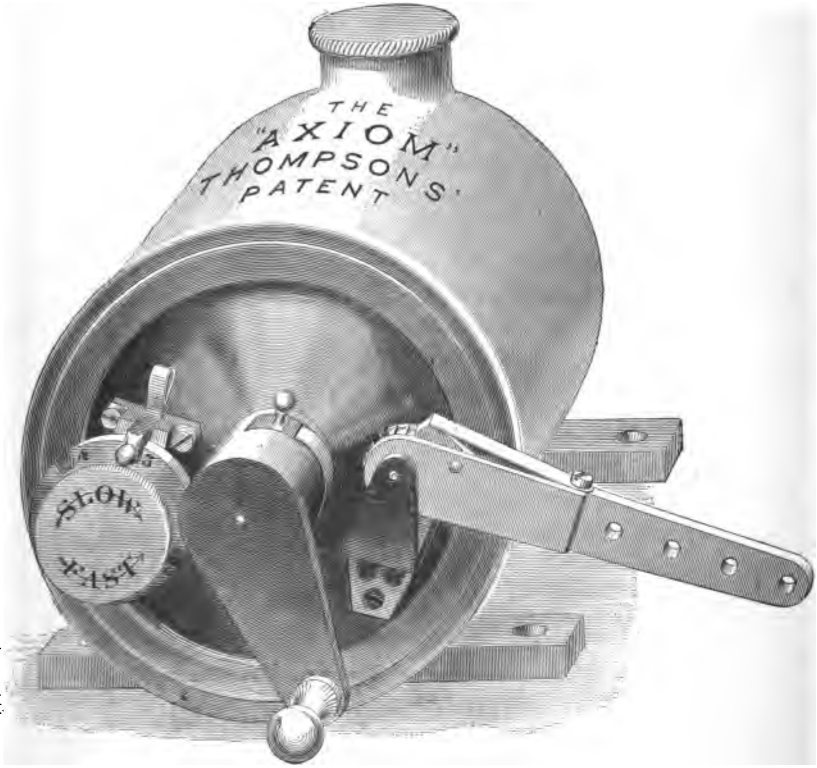


Fig. 12.—Axiom Lubricator.

In Fig. 13 the grease-cylinder is placed on the back of the standard, with pipes leading from it to all parts of the engine which require lubrication. The grease is forced through these pipes by means of a screw, which is kept

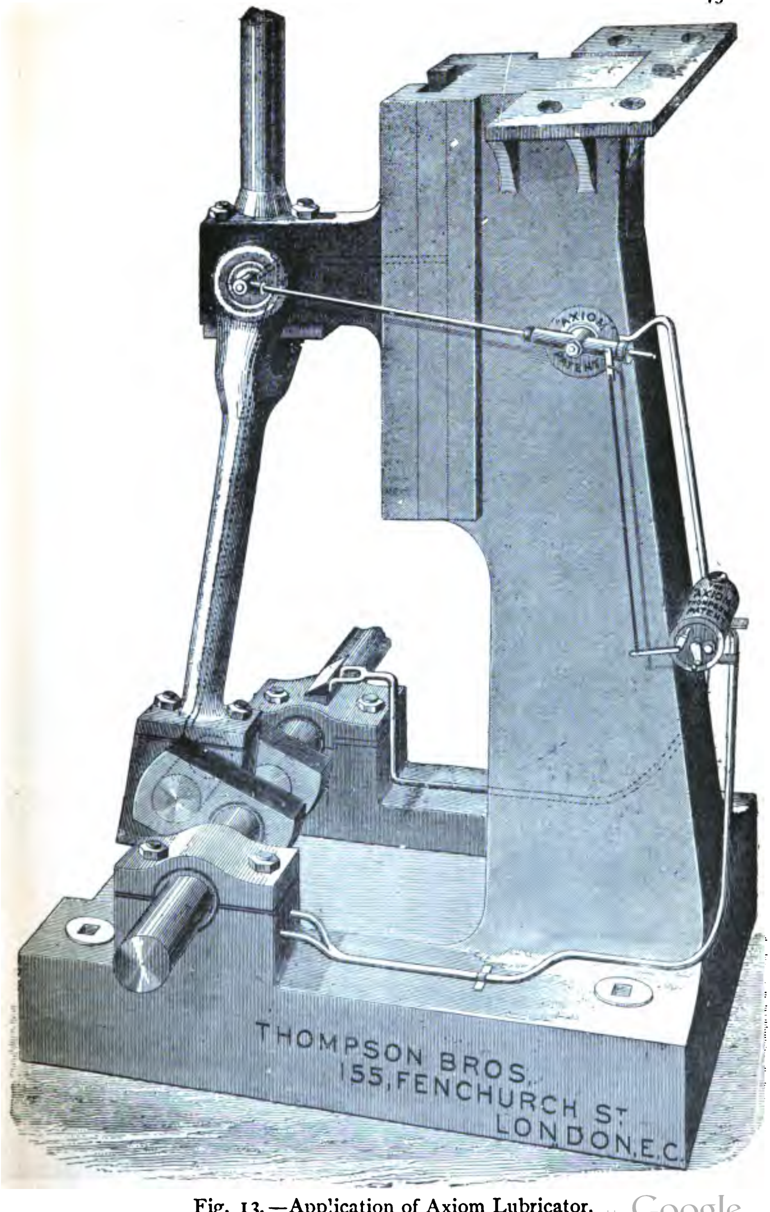


Fig. 13.—Application of Axiom Lubricator.

slowly and continually turning in the grease-cylinder, so that the grease is forced through the tubes. The arrangements are such that the grease to every bearing can be regulated, and sufficient propelling force exists to lubricate the heaviest journals. The method has proved successful in every instance, and is emplcyed at the City of London Electric Light Station, where it has overcome many difficulties connected with the older forms of lubrication. Messrs. Thompson call the system "The Axiom."

Fig. 14.—Crosby Oil-Cup.

A very pretty and convenient form of oil-cup is made by Messrs. Crosby. The supply of oil is adjusted once for all, and it may be turned on, when desired, by raising a small lever from the horizontal to the upright position, the reverse action turning it off. To give a little extra flow of oil when starting (which is sometimes found necessary), after placing the lever upright it can be pulled upwards slightly, when the required result is attained. This oil-cup is shown in Fig. 14.

As this little book deals only with private installations, there is no need to go into the details which apply to large works. However, a private installation

is here supposed to go up to 3,000 16 c.-p. lamps; this being considered a very wide margin, because the largest country house rarely requires more than 500 lamps.

The following two illustrations show types of

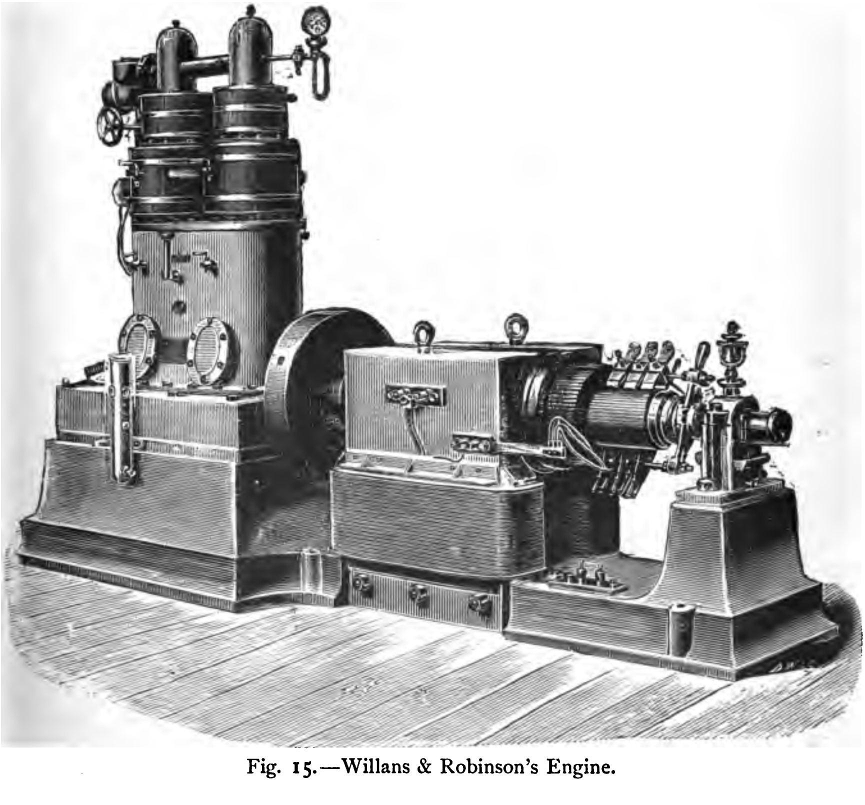


Fig. 15.—Willans & Robinson's Engine.

electric-light engines largely in use at the present time. Fig. 15 is a Willans & Robinson engine; it is shown coupled to a dynamo. Fig. 16 is a vertical engine made by the Brush Electrical Engineering Company

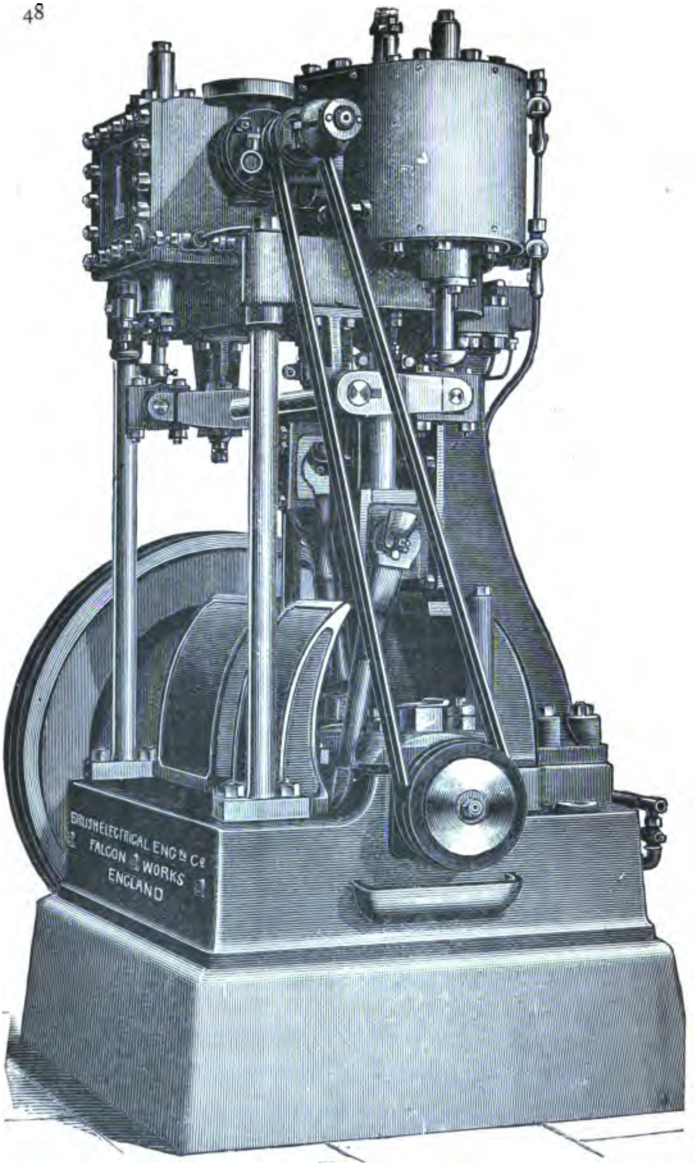


Fig. 16.—Brush Corporation Engine.

Both these engines are of the high-speed type. The couplings are generally flexible in a slight degree, in order that neither the shaft of the engine nor that of the dynamo may be bent or strained, should the alignment be imperfect. Magnetic couplings are sometimes employed, one half being an electro-magnet and the other half its keeper. When the current is cut off from the electro-magnet, the coupling is out of action and the dynamo comes to rest. Clutches are better.

Engines used for electric lighting should have automatic governors, which "cut off" and thus "expand" in proportion to the load.

It may be taken as a rule that engines of the best manufacturers can be worked continuously to three times their nominal horse-power, with economy, at maximum boiler pressure. Cheaper engines are not strong enough to stand a continual strain of more than twice their nominal horse-power. The maximum power given off at any time is clearly proportional to the steam pressure.

It is always safest, in practice, to adopt the following method in purchasing a steam-engine required for a particular installation. Allow sixteen 8 candle-power lamps per brake horse-power, when the engine-house is within 100 yards of the residence; if farther off, fourteen to the horse-power; but never less, because by making the leads larger, this condition can always be obtained, excepting under peculiar circumstances, which would arise only in the event of great distances intervening between the generation of the current and the place where it is used, when it may be cheaper to light fewer lamps per horse-power than to have larger mains.

In making the calculation, consider the maximum

brake horse-power of the engine one and a half times the nominal horse-power. There will then be no chance of falling short of power, as there will be a large margin which can be made available by slightly raising the steam pressure. The boiler should always have a larger nominal horse-power than the engine, in order to secure a good steam supply and to allow longer intervals between the "firings."

The higher the pressure of the steam, the more is expansion possible, and the greater is the economy in coal, since the large amount of heat required for the conversion of water into steam, which is rendered latent, is not wanted a second time for further raising the pressure; and all the heat imparted after evaporation is available for useful work, with a trifling exception.

Expansion beyond a certain point is best accomplished by the use of two or more cylinders, such engines being called "compound." But these engines are not recommended for private installations, unless there is skilled labour; because the simpler the engine the less chance is there of its getting out of order.

In respect also of high-speed engines, these should be avoided for private use, except in confined situations, when their presence may be found indispensable. One hundred revolutions per minute of the fly-wheel suffice for all purposes in engines from ten to twenty nominal horse-power, 150 per minute in smaller engines. After twenty nominal horse-power the speed given to the fly-wheels is less. All these machines come under the designation of "slow-speed engines."

Much talk is made of saving fuel by very high expansion, but to the private installer it is not of great consequence; for the saving is generally more than

counterbalanced by the extra expense of locomotive tubular boilers, compound engines, and so forth, which require more attention than the Cornish multitubular boiler and simple engine. There is also more anxiety, due to higher boiler pressures.

To obtain an actual idea of the saving effected by the use of a compound engine as compared with a simple engine, take coal at 20*s*. a ton; and, for an installation of 100 8 candle-power lamps used 2,000 hours in a year, supposing 6 lb. of coal per indicated horse-power per hour are used for simple working, and 2 lb. for the most economical compound methods, the result would be 30*l*. to 40*l*. per year. On the other hand, there must be at least 20*l*. to 30*l*. allowed for faulty boiler tubes, drawing them for cleaning, keeping all fittings steam-tight against the high pressure, increased interest, and so on. But this is an exaggerated case, for in no 100-light installation would it be possible, in practice, to light up the whole 100 lamps for 2,000 hours a year. The actual saving, under the most economical method, probably would be less than 10*l*., which is a very small proportion of the total cost. Although 2 lb. of coal is stated by some makers to give 1 indicated horse-power, it may be questioned if, in fact, it can be done under 3 lb., excepting in very large engines. The risk of breakdown is far less with lower pressures and slow-running engines.

It is strongly recommended that the boilers be insured against explosion and against collapse of flues; also that the engine-driver be insured in respect of injury or death, consequent upon such accidents. The premium is very small, and, as the company insuring makes periodical inspections, no risk, legal, moral, or pecuniary,

is incurred by the owner. A rough idea of the cost may be obtained by taking a boiler of 12 nominal horse-power, used with an engine of 10 nominal horse-power, and working, with greatest economy, at 36 indicated horse-power. This can be insured in the Boiler Insurance Company of Manchester for 2,000*l.*, including the engine-driver; and the premium in respect of both will be about 5*l.* a year. The insurance covers all damage to buildings and to machinery caused by an explosion, also compensation to the driver in case of injury, or to his family in the event of his being killed. It is, therefore, well worth while to take this precaution. If the engine-house is made of incombustible materials, there is no necessity to insure against fire.

Gas-engines also can be insured. The cost of insuring a 14 horse-power nominal gas-engine against injury to the extent of 50*l.* is 3*l.* per annum.

When the engine is worked daily, much fuel is saved by banking up the fire at night, instead of drawing it, since the water is kept hot for the next day. This is a perfectly safe proceeding, if an automatic feeder be employed. There should be two water-gauges, and two safety valves placed on the boiler, to permit of perfect inspection and to secure safety. Suitable boiler composition should be employed to prevent scaling; and in order to obtain the right kind, it is advisable to have an analysis made of the water. Indicating apparatus ought always to exist, by which means the working parts of the engine may be examined in a scientific manner periodically, and thus undue mechanical and electrical waste can be checked.

We may now turn to the counter-shafting and belting. For electric-lighting machinery, clutches are generally

preferred to fast and loose pulleys, because they occupy less space and are more easy to work, and because the belting is wide. Any good belting answers the purpose, provided there be no raised joint. Chain belting, made of leather links only, has been much used, but is most undesirable when combined with iron or steel links, because the latter rapidly saw asunder the connecting pins. In all cases periodical examination should be made so as to observe the state of the links. There are many good makes of belts in the market. One kind of belt comes from America (Cooper's), and is sold in London. This leather has at least twice the strength of the ordinary material, and it grips exceedingly well; but for double belting it might be found to stretch when large powers are transmitted. Contrary to the ordinary practice, this particular belting must be placed with the face side next to the pulley. When counter-shafting is employed, it is best to drive it by double belting and carry single to the dynamos.

Fly-wheel centre to shaft centre, about 15 feet, is the most suitable distance; and all driving pulleys should have a sufficient diameter and face for obtaining the necessary grip. Belts should not be too tight, and the sag should be given at the upper, not the floor, side. (One exceptional case has been referred to.) The advantage is, besides avoiding the possibility of rubbing on the floor, a better grip round the pulley with increased tension. Belt syrup, free from resin, should be used, if slipping occurs when the tension is correctly adjusted, and when the load is not beyond the power of the engine.

Occasionally in the sag of the belt a wave is produced, which is reflected in the lamps by blinks. This

wave can generally be removed by tightening the belt; or, this failing, by making the machinery firmer; and sometimes by slightly raising or lowering the speed of the engine.

Counter-shafting should be solid, and all arrangements made so that the belts may run horizontally; which permits of their being left slack, utilising their weight for the tension and saving the bearings from undue wear and tear. It is best, when space permits, to place respectively the engine and dynamos on opposite sides of the counter-shaft; the belt tensions thus balance one another on the counter-shaft bearings, and much friction is prevented.

The action of oil in the bearings is peculiar. The shaft and brasses never come into actual contact, oil always intervening, no matter what the load may be; so the friction really consists of shearing a thin surface of oil. It is thus seen why the "friction load," which means the power employed to run the machinery free, is about the same when a load, however great, is added. The condition is that oil or grease shall always be supplied to make good the loss. Hence, if the indicated horse-power to run free requires, say, 4 horse-power, and a load of 1 horse-power is added, the indicated horse-power will be 5; and so on. It is evident, therefore, that the heavier the load put upon an engine, within its capacity, the greater the efficiency. In fact, such an engine, in practice, would require almost the same quantity of coal or gas and undergo the same wear and tear in lighting one lamp as probably ten lamps, for this work would be very small as compared with its friction load.

The indicator mostly in use is that of Richard. It

can be placed upon gas- as well as upon steam-engines. The original form of this indicator has been modified in many ways. The moving portions of the apparatus have been lightened to obviate possible errors, and in other cases not only is lightness studied but size also, especially when the indicator has to be employed with engines of high speed. With indicating apparatus of this class it is not an uncommon practice to have a reducing gear inserted between the moving parts of the engine and the indicator. This apparatus is so well known that a description of it is unnecessary. The ordinary type of indicator, as made by Messrs. Elliott and other manufacturers, is probably chiefly in use. With high-speed engines Messrs. Crosby's indicator is much employed. There are two special forms, among many others, which should not be overlooked. One is that of Professor Vernon Boys, which is really a power meter. This apparatus will make the usual diagram on a miniature scale when required; at other times it becomes a continuous record of the power given out by the engine. This is accomplished by the indicator motions, which are of the usual kind, moving a cylinder and a friction wheel, which latter rests upon it, the result being that the integrated motion is registered upon a dial. The power given out by the engine at any time can thus be ascertained, a time-constant being taken into account. To make an observation it will only be necessary to watch the advance of the needle upon the dial for, say, one minute; the distance which the needle has passed over gives the desired result, viz. the indicated horse-power during the period of observation. The divisions on the scale can be made direct reading without the use of any constant, if so desired; this

adjustment being made by the user of the apparatus and not by the maker.

The other indicator is one designed by Professor Perry. In this case the two motions of the indicator are combined in the movement of a small mirror. A ray of light is arranged to be reflected from this mirror upon a card or small screen. The diagram is there traced out as a white curve on a dark ground. As many moving parts existing in the ordinary indicator are absent from this one, a very true result is obtained.

Dynamometers are occasionally required in an engine-

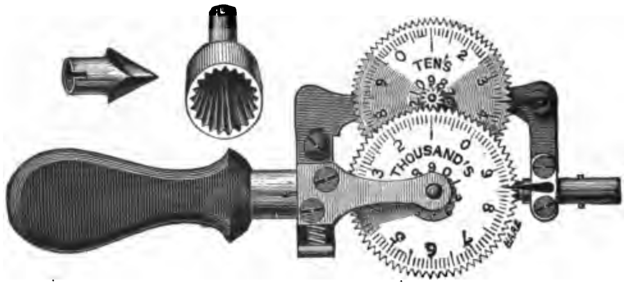


Fig. 17.—Speed Indicator.

house, but, when good electric standard measuring instruments exist, it is quite possible to make the measurements electrically.

In the engine-room a speed indicator is always to be found. The general form of this instrument necessitates the use of a watch with a seconds-dial, and the indicator must be applied to the moving shaft when the observation is taken. To render the taking of speed more convenient, a counter has been brought out in the United States under the name of Heath's Patent Self-Timing Registering Speed Indicator. The apparatus is,

in appearance, very similar to those in general use, but it contains a watch-work which runs half a minute at a time. It is wound up by pushing in a stud, and started by pressing another button, the former action also setting the hands at zero. The counter is applied in the usual manner to the end of the shaft, and when the

Fig. 18.—Counter.

operator is ready, the starting-button is pressed; which permits not only the train to run, but also the hands to rotate. At the end of the half-minute the hands cease to move, although the spindle may still be running, and the reading indicates the revolutions during one minute. Other counters, on a similar principle, have appeared from time to time.

An ordinary, and a good, form of speed indicator is shown in Fig. 17.

By pressing a spring the cog-wheels can be freed to enable the dials to be set back to zero. The plate also shows two forms of centres. With this apparatus the time must be taken by a watch.

Fig. 19.—Counter.

Messrs. Berend, of 61 Fore Street, E.C., supply an exceedingly handy form of the counter, shown in Figs. 18 and 19. Detailed description is unnecessary, but it may be pointed out that the numbers on the dial shift according to the direction of the revolution, in order that the reading may always be correctly taken. The only difference in the Figs. 18 and 19 is the position of

the numbers on the dial to illustrate what has been mentioned.

Messrs. Woodhouse & Rawson have introduced a very convenient form of speed indicator, which gives the speed upon a dial. Its functions are fulfilled by an electrical arrangement, and it is made in a portable form. The mechanical portions are so contrived that low and high spceds are read with the greatest ease.

Fig. 20 shows an Engine-Room Fixed Speed Indicator, generally termed a Tachometer. Sometimes to

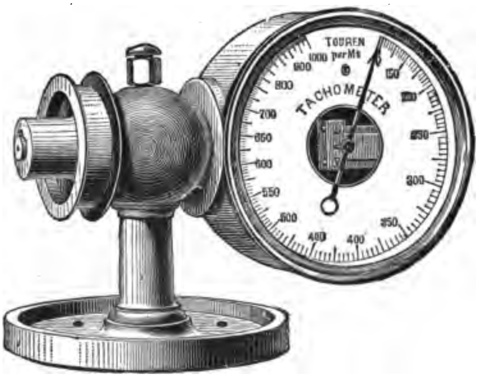


Fig. 20.—Tachometer.

avoid the necessity of using a watch, the clock in the engine-room is so arranged that it shall strike a bell once every half-minute, directly or by means of an electric single-stroke bell. There is such an arrangement in the Broomhill engine-house. The clock is wound by pulling a string, and is started by moving a small lever. The bell is supplied with current of a 100-volt circuit, a 16 candle-power lamp being inserted as a resistance. Thus each time the bell rings, the lamp lights up. The sight signal is often handy.

CHAPTER II.

DYNAMOS AND MOTORS.

THE patterns of dynamos in the market are very numerous, and those of the best makers give approximately the same efficiency and possess the same qualities generally. The slow-running dynamo, say from 500 to 700 revolutions per minute, should be chosen, since there is less vibration, and less wear and tear with these than with machines speeded from 1,000 to 1,500. The low-speed machines, however, are more expensive. It is imperative to have solid foundations, and, for the bearings, self-oiling or grease arrangements are essential.

The machines must be kept perfectly clean and dry, and should not be tampered with. For the mechanism, all that requires attention are the commutator and brushes. Both must be kept scrupulously clean, and sparking in any form should be guarded against. All modern machines have the brush-holders adjustable, so that full directions will be given for producing the best results. The commutator soon becomes worn by sparking or by too heavy a pressure of the brushes. When much wear takes place, the truth of the commutator becomes destroyed; instead of wearing down equally, it gets eccentric and assumes all manner of shapes. Re-turning in the lathe is then the only cure, but this irregular wear

can be almost entirely obviated; in which case the armature need not be removed for turning more than once in three or four years, if as often. If any plates in the commutator are softer than others, or contain flaws filled with solder, then nothing will prevent the unequal wear, except by substituting good plates for bad ones. Rolled copper is the best material for commutator plates; it wears evenly, keeps bright, and contains no flaws.

It should be well borne in mind that, if the commutator is not kept in good order, the loss of efficiency may be enormous; and, eventually, it will be impossible to use the dynamo. In addition, the least unequal wear causes the brushes to jump, making the light flicker, and the faulty places become worse daily. When faults are confined to one or two plates, they are termed "flats." A faulty coil in the armature might create a flat, but the case is rare.

Modern dynamos and motors, if the brushes are properly adjusted, run free from sparking, provided the load is not too great for the machine.

Five things must be attended to for preserving these parts in good order:—

1. The brushes must have a proper inclination.

2. The pressure should be adjusted properly.

3. The lead must be given correctly for the current.

4. Occasional application of oil or grease to the commutator should be resorted to.

5. Scrupulous cleanliness, in regard to the brushes and commutator, must be observed.

1. The brushes, in most cases, may be more inclined as they are pushed further through their holders. The inclination is right when the commutator runs

smoothly under the brushes without noise, and they should offer a good surface to conduct the current. When new brushes are inserted, they must have their ends ground or filed to the curve of the commutator. This is best done by clamping a brush in a vice, between two pieces of wood, the end of the brush only projecting, so as to avoid spreading the plates or wires during grinding and filing. Unless a good surface of contact exists between the commutator and the brushes, it is often difficult to obtain a current from the machine. When the commutator wears out of truth the inclination must be increased. It is imperative that the brushes should rest at the extremities of the diameter of the commutator. Copper gauze brushes are probably the best to employ, in nine cases out of ten.

2. The pressure need not be great, but only as much as is necessary to ensure perfect contact during running; more than this is unnecessary, so long as the commutator runs true. Great heating of the commutator and armature is often due to the friction of the brushes when too much pressure is put on.

3. The lead next claims attention. The neutral lines on the commutator are the two lines which can be drawn along the plates at the extremities of a diameter which coincides with the vertical or horizontal, according to the pattern on which the dynamo is built; and this diameter, if produced, would meet the yoke, or yokes (*i.e.* when viewed in "projection"), of the field-magnets. These, theoretically, are the places where the brushes should rest; but, in point of fact, the neutral lines become displaced when a current is taken from the machine, and the displacement increases as the current is larger. To enter into the many reasons for this dis-

placement is not within the province of this book; only the consequences will here be considered. It may, however, be mentioned that the lead arises from the fact that the armature is magnetic and reacts on the field-magnet's magnetism in such a way that the neutral points become shifted. The less magnetic the armature, compared with the strength of the field-magnets, the less the displacement. If the brushes are not placed upon these neutral lines, sparking ensues, excepting in specially constructed dynamos. The brushes having been adjusted in accordance with instructions 1 and 2, all that is necessary to set them for the correct lead is to rotate them on the frame to which they are attached for this purpose, until a point is reached when all sparking ceases or is reduced to a minimum. The frame is then clamped; but, as this lead varies with the work done in the outer circuit, it must be set according to the amount of current taken off at any time. It is of the highest importance that the brushes should rest on the plates situated at the extremity of a diameter. As a rule, one pair of such opposite plates is marked with a centre punch; if not, the owner of the dynamo can do this, for it is found at times to be an advantage to know the true opposites, by direct observation. Generally, finger indicators are attached to the brush-holders to facilitate the adjusting of the brushes, and to ensure their being on exactly opposite sides of the commutator. In good dynamos, when the brushes are properly set and everything is clean, a point, where there is no sparking, can always be found. The angle of the arc, which lies between one of the theoretical neutral lines and the actual neutral line, is called the "lead," and this may be positive or negative. In the case of a

dynamo the lead is positive; with a motor it is negative. When the brushes are advanced from the theoretical neutral lines in the direction of the rotation of the armature, the lead is positive and varies in accordance with the current that is flowing into the brushes. When moved in the contrary direction, a negative lead is given. The margin of the non-sparking position is far larger with motors than with dynamos. This is due to the manner of using, and not to the design of the machine.

In the older dynamos the lead was very considerable, but in modern machines one-eighth to a quarter of an inch is generally all that is necessary for every current the machine has been made to give. It is essential to advance or retire the brushes in order to suit the current; otherwise sparking begins when the current is much varied. Consequently it is always best to arrange matters so that, while the machinery is running, a fairly constant current shall be taken.

4. The commutator from time to time should have a little oil or grease applied to its surface. Grease is the best, and if made from petroleum one application will last a day's work, provided the pressure of the brushes be light. The best way to apply the grease is with the finger, or a piece of rag; not waste, as particles of cotton may get drawn under the brushes. At no time should the grease be applied larger than the size of a pea. Inferior dynamos require frequent lubrication. Some persons use blacklead, but this is undesirable because of its conducting properties, which are sure to lower the efficiency of the machine. This substance may be employed with alternate current machines, since the commutators do not consist of a series of insulated plates.

5. Cleanliness is essential, or sparking is certain

to result: the least speck of grit is apt to start a "flat."

Copper dust cannot possibly be formed, if all the precautions mentioned have been taken; but, should any collect, it must be carefully removed from the machine. Undue pressure of the brushes produces copper dust in great quantities by tearing away the commutator and brushes, and this damages the machine, therefore, when cleaning the machine, the wear should be observed. All alterations ought to be made when the dynamo is standing with the brushes raised. The lead alone must be adjusted while the machine is running.

These directions apply to machines which are not of the alternate current type, although the instructions in regard to cleanliness apply to all machines. A few words on alternators follow later.

If the attendant has any doubt as to whether the dynamo is acting, it is only necessary for him to bring a piece of iron near the field-magnets, and to observe whether the latter are strongly magnetic; but while he is doing this he must take care not to allow the iron to be drawn out of the hand, so as to damage the machine.

Occasionally it happens, though very rarely, that on starting the dynamo the field-magnets will not excite, and consequently no current is produced. A few taps with a mallet, or hammer, on the yoke of the magnets will set up, in the iron, a weak magnetism, the presence of which is absolutely essential in the first instance. The explanation is that the vibration caused by the tapping frees the atoms of the iron sufficiently to permit of the earth's magnetism placing a large number of them in such a polar direction as to give an external magnetic

field; or, in other words, the iron becomes feebly magnetic. The failure may also arise from want of proper contact of the brushes upon the commutator. If these two causes do not account for the dynamo not acting, the circuit on the dynamo is probably broken at some point.

The brushes should on no account be lifted while the dynamo is running. The insulation may be much injured by this action, and a bad place is made on the commutator. In large machines such an act may result in a violent or even dangerous shock being given to the individual.

The commutator, while running slowly, occasionally requires cleaning with fine sand or glass paper; but emery paper should not be used. If its condition is very bad, and turning in the lathe cannot be resorted to, it may be smoothed with a worn-out file. Of course, filing does not make the commutator true, but it mends matters for the time. When cleaning the commutator the brushes should be removed, so that they do not become charged with grit.

A lathe compound-slide rest may be suitably fixed to the main casting of the dynamo, so that the commutator may be turned up at any time without removing the armature. The machine must be run at very low speed during the operation. The commutators of motors rarely require touching.

Emery should never be brought near the dynamo, for if any of the powder gets into the bearings it is almost impossible to get rid of it; and hot bearings may be the result for many months afterwards, however carefully the journals may be cleaned.

Mr. Sayers read a paper before the Electrical Engineers, in May 1893, suggesting an auxiliary winding

upon the armature in order to do away with sparking under every condition. Other suggestions for a similar purpose have been made from time to time, such as the addition of a suitably placed condenser, and, as proposed by the author, the addition of two auxiliary brushes with some special form coil between them; the object in all cases being to annul the E.M.F. set up in any coil on the armature, which is short-circuited at the moment the brush passes over to adjoining commutator plates. Mr. Sayers' method is very simple, and appears to be satisfactory. The author's plan could probably be applied to all dynamos without altering their winding. The chief advantage of this addition is that the output of any dynamo may be somewhat increased, providing that the wire will carry the current without undue heating. Also direct-current dynamos, to produce a current with a higher E.M.F., could be made without the difficulties at present existing, which chiefly consist in the arcing that occurs between the plates as they pass from under the brushes. In the high-pressure direct-current type of dynamo, as now made, gaps between the commutator plates have to be wide; and in some cases a powerful draught of air is employed to blow out the arc which is created. Professor Elihu Thomson was the first to adopt the blower.

Carbon brushes have become the fashion of late. These are convenient when a motor has to run sometimes in one direction and at other times in the opposite direction; but they are not so smooth running, and not so sparkless, as the copper gauze brushes, especially when it is desired to vary the speed of a motor by shifting the position of the brushes upon the commutator. Altering the speed of a motor in this manner is not the most effi-

cient method, but, in the majority of instances, efficiency is not studied when a motor is required to have very variable speeds ; and shifting the brushes is an exceedingly simple way of producing the desired result. The method can be employed only in motors of the best make, or sparking follows. It must be borne in mind that the dynamo and the motor are one and the same machine, according to the way it is used—*i.e.* whether turned by an engine to produce current, or a current passed into the machine to produce motion. All instructions given in reference to a dynamo apply with equal force to a motor.

The temperature of the coils on the dynamo should never rise high enough to prevent the hand being freely placed upon them. It is well occasionally to observe the temperature of those parts which can be touched, provided the machine does not give a dangerous E.M.F. (*i.e.* over 250 volts); and the armature can be examined for temperature by a suitably arranged thermometer, by heat indicating paint, or on stopping.

Many suppose that a dynamo sold to light one hundred lamps cannot be used for more. This is not so, for ten times this number might be added in some cases, but the wire on the armature would become so hot that destruction of the insulation would occur, and possibly fusion of the wire. The meaning of a 100-lamp machine is simply that the wire on the armature is only large enough to carry a current for a hundred lamps of given power ; so that attention is necessary to observe that this limit be not exceeded by any accident or stupidity, such as putting a hundred lamps on the circuit which may require a larger current than a hundred intended lamps. It must not be inferred that an unlimited current can be taken from a dynamo, for after a

certain point the inductive effects limit the output; and, in the case of the shunt dynamo, after a certain point is reached, no current will be produced at all.

The drum armature is preferable to the gramme ring form. It is more economical, and sparking at the brushes can be entirely obviated by its use. Modern dynamos and motors generally have their armatures wound in this manner.

Makers usually give the power of a dynamo in three ways: (1) lamp power, thereby indicating the maximum number of 35 watts (8 candle-power lamps) the machine is intended to light; (2) by the current and E.M.F. it is intended to give; (3) by designating its power in units, or kilo-watts, one such unit being 1,000 watts. A Board of Trade unit, as applied to lighting, is 1,000 watt-hours; a watt being the unit of measure of force.

In all cases it is necessary to know the pressure the machine is intended to give, in order to obtain suitable lamps to use in connection with it. The best way of reckoning the power of a machine is by units, because the carcase (*i.e.* the frame) of any particular machine may be wound to give any desired E.M.F., and the units divided by the pressure give the current obtainable. For instance, a 10-unit dynamo for 100 volts will produce 100 amperes; the same carcase can be wound to give 50 volts and 200 amperes, and so on. But the speeds will not be the same in all cases.

Practically there are three ways in which a dynamo can be wound, although there are many other fancy windings which have their uses in special cases. Fig. 21 is a diagram of a series-wound machine, in which the details are shown; F being the magnet, A the armature, and G the commutator.

1. Shunt-winding (see diagram, Fig. 22). In this case the magnet coils are in shunt, and only a small current passes through them, usually from 2 to 5 amperes. It is evident, therefore, that the less resistance there is in the outside circuit, the smaller will be the current passing around the magnets; and if the resistance of the outside circuit approaches *nil*, the machine will give no current at all, since the field magnets will not be excited. On the other hand, the higher the resistance of the outside circuit, the greater

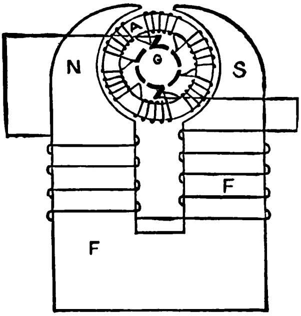


Fig. 21.—General Diagram of Winding.

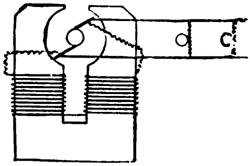


Fig. 22.—Diagram of Shunt-Winding.

will be the excitation of the field, and the higher will be the E.M.F. of the current. Putting this in other words, the larger the current taken from a shunt-wound dynamo, the lower will be the E.M.F. until it reaches zero. Therefore, it is evident that such a machine is not self-regulating.

2. The series-winding (see diagram, Fig. 23). In this case the main current passes through the field-magnet coils on its road to the outside circuit. It may, therefore, be gathered that the larger the current flowing to the outside circuit the greater will be the excitation of

the field and the higher will be the E.M.F. The inverse also is true. Consequently, the larger the current flowing to the outside circuit, the higher will be the E.M.F.; which is the converse of the case of the shunt-winding. These machines also are not self-regulating.

3. Compound-winding (see diagram, Fig. 24). It must be clear that, if a compound could be formed of windings described in Nos. 1 and 2, a self-régulating machine could be produced. This is done by passing the main current through the field coils, and, besides, there is a supplementary shunt-winding which permits a small current to flow around it. The adjustments are

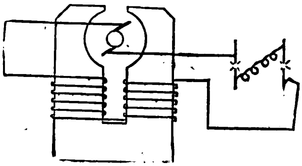


Fig. 23.—Diagram of Series-Winding.

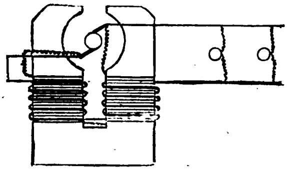


Fig. 24.—Compound-Winding

so made that the tendency of the E.M.F. to fall for a smaller current passing through the series-winding is counterbalanced by the increased current passing through the shunt-winding. Dynamos wound in this way have, in order to give a constant pressure, to be run at some given speed, termed the "critical speed." At other speeds the regulation is imperfect.

All dynamos have a critical speed, which is the most efficient one, but in the case of shunt-wound and series-wound machines there is a considerable latitude allowed, so that the rate of speed may, in a measure, be adjusted for the E.M.F. required.

Electro-motors need exactly the same attention as

dynamos, their construction being identical, except that the lead given must be negative. The speed of a motor is almost invariably higher than that of the machine it has to work, so that a counter-shaft must be employed in most cases; and this is better than worm-wheel gearing, for many machines may be worked off one counter-shaft if desired, and there is less friction. Slow-speed motors can be made, though for their power they weigh heavier than the high-speed ones. It is best, in a workshop, to have a small motor to every machine, so that each workman may have his own motor under control; and this method is the most economical.

Notwithstanding that the loss between the engine and the lathe, or other machine, is probably 50 per cent., still electric motors are economical. Heavy main shafting, running all day, is thus avoided. Ordinary main shafting, with the belts, probably absorb 30 per cent. of the power transmitted, especially when the alignment is faulty, which is almost invariably the case. The expense of electric power in the first instance is no greater than the present method of obtaining power in a factory, and the difficulty of maintaining regularity of speed with motors is purely imaginary, for in practice no trouble is experienced on this head. An illustration may be given where the speed of the motor does become considerably altered by the variation of the work put upon it, and where it proves of advantage. When a fine light cut is taken in a lathe, much greater speed is desired than when taking a large and heavy cut. In the latter case, more power also is required. Now these two alterations in speed and power are exactly what may be obtained from a motor (within reasonable limits) without any adjustment, since, in any motor for small power, it runs

faster and takes less current than when doing heavier duty. For any particular class of work, by inserting resistances with a hand switch, almost any desired speed may be had, or the brushes may be shifted. It is best to have motors series-wound, because the field-magnets become excited the moment the current is turned on ; and in starting a motor, it is preferable to turn the current not full on at once, but gradually through resistances by means of a suitable switch. Clutches and loose pulleys are rarely needed with motors, since the starting and stopping are more easily done by employing a switch. In cases where absolute regularity is required, governors may be used. The method successfully tried by the author, of drawing the armature in and out of the field in the direction of its axis, has answered as well as any other system devised, the ordinary centrifugal governor being employed to produce the changes.

To start a shunt motor one brush should be raised before turning on the current, and after this is done the brush is dropped. The field-magnets consequently become magnetised before a current traverses the armature. Instead of lifting the brush a switch may be employed to cut the shunt-winding, which is sometimes more convenient.

A motor should not be started and then stopped immediately, but it should be allowed to get up its speed before switching off. This avoids cutting a large current. Turning on a motor should be done gradually through a resistance, unless the machine be a very small one, and taking a maximum current not exceeding 2 or 3 amperes.

It must be remembered that, although in workshops some lathes and machines are kept constantly running

the majority stand a good part of the day, not all at one stretch, but by summing up the stoppages. At such times a motor is stopped and there is no waste, for the generating dynamo absorbs power from the engine proportional to the work demanded from it. A great economy results from this which cannot exist when main shafting is used. Lathes, drills, and other tools may be moved as found convenient, without considering the position of the main shaft. This is in itself a great advantage.

It is of the highest importance that the centre of gravity in a dynamo or motor should be low, also that the armatures should be perfectly balanced, so that vibration may be reduced to a minimum, or even entirely overcome. In the best models the poles of the magnets point upwards, and thus are free. When the poles are fixed to the base (which must not be made of a magnetic metal) there is considerable magnetic leakage.

The direction of a current through the field-magnet coils, compared with the direction of a current passing through the armature, gives the direction of rotation, so that, in the case of shunt machines, if a suitable switch is employed for reversing these relations, the motor will run the opposite way; and a motor capable of running in either direction is produced. But care must be taken that the brushes are of an upright pattern and generally made of carbon, to permit of the commutator running either way without injuring the brushes. In a series motor, a large shift of the brushes will bring about a reverse rotation.

There will now be given a few examples of direct-current dynamos, which are mostly in use at the present

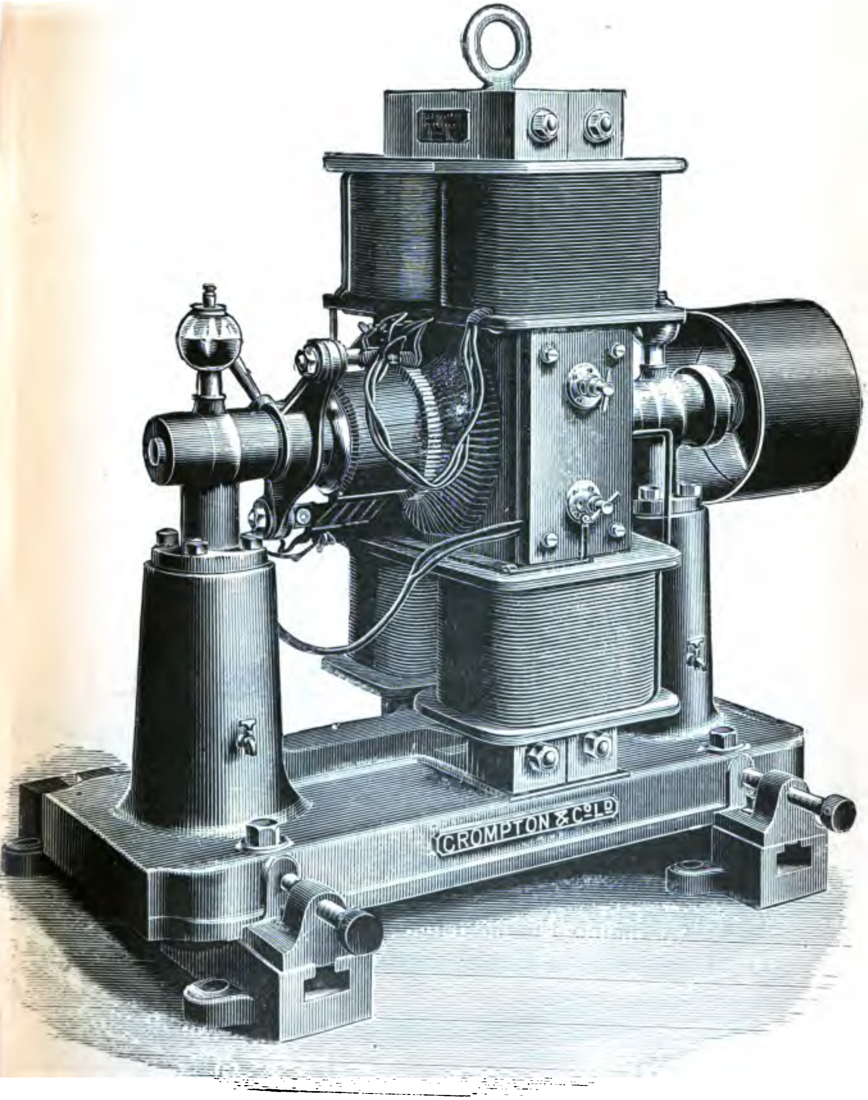


Fig. 25.—Crompton Dynamo.

time; and then a few words will be said in respect to dynamos of the alternate-current type.

Fig. 25 illustrates a large dynamo by Messrs. Crompton.

Fig. 26 is a dynamo by the same firm, but of a cheaper type.

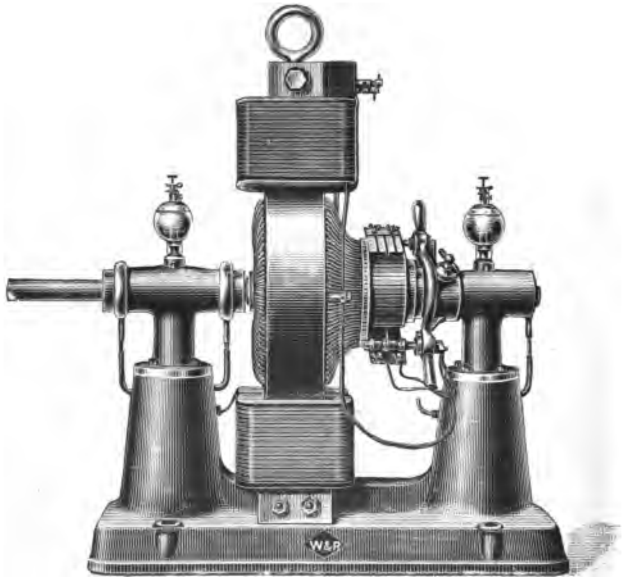


Fig. 26.—Crompton Dynamo.

Fig. 27 is a view of an Edison-Hopkinson dynamo. In this dynamo the field-magnets were improved by Dr. Hopkinson, and the armature is of the Siemens' wound-drum type.

Fig. 28 represents the Manchester dynamo, made by Messrs. Mather & Platt.

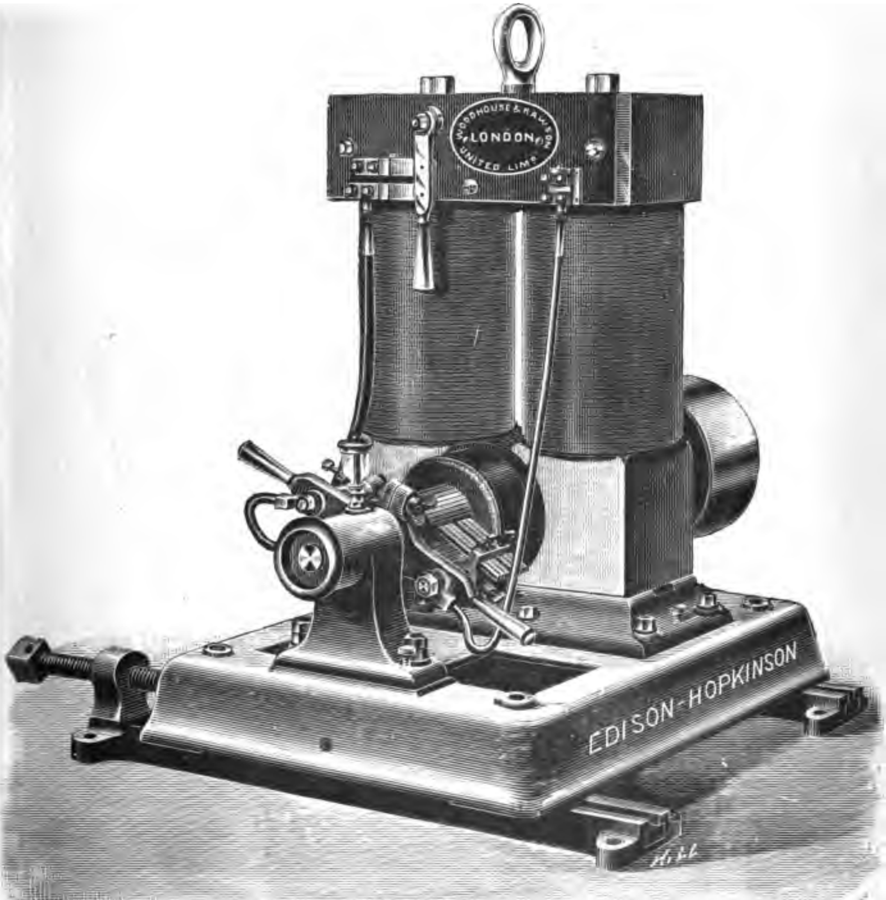


Fig. 27.—The " Edison-Hopkinson " Dynamo.

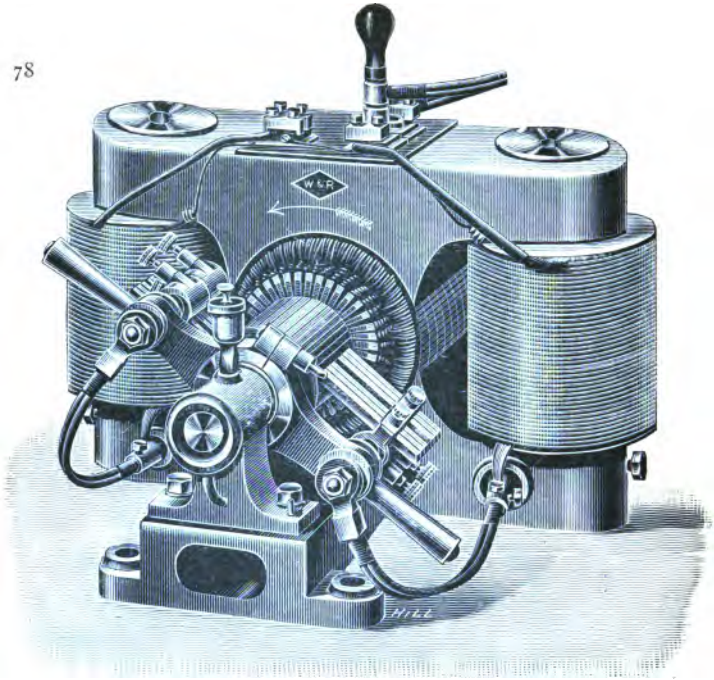


Fig. 28.—The "Manchester" Dynamo.

Fig. 29 is a Siemens dynamo.

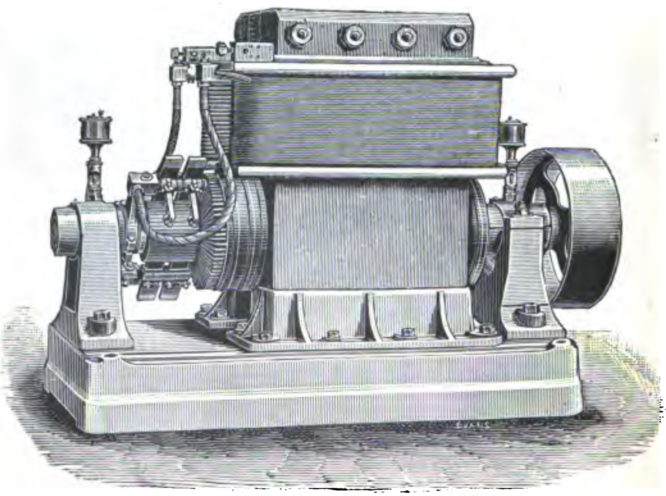


Fig. 29. —Siemens Dynamo.

Fig. 30 shows the "Phœnix" dynamo ot Messrs. Paterson & Cooper coupled to a Brotherhood engine.

Fig. 31 represents the Kapp dynamo, made by Messrs. Johnson & Phillips.

Figs. 32 and 33 show two forms of Messrs. Goolden's dynamo, the latter for use in mines.

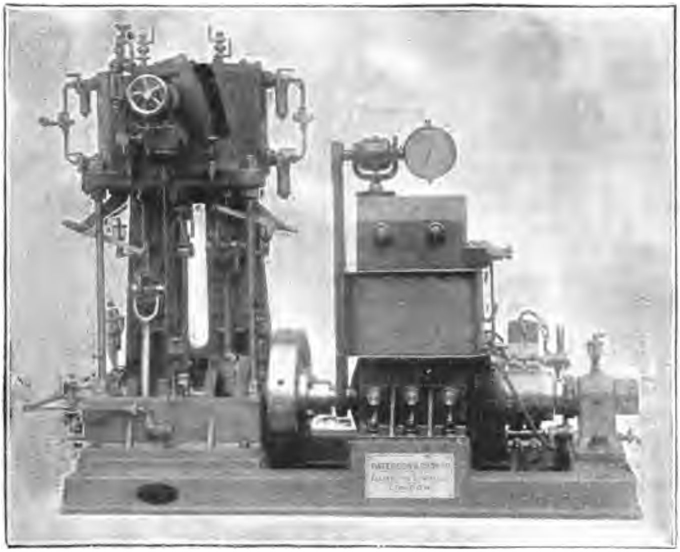


Fig. 30.—The "Phœnix" Dynamo.

Motors intended for use in mines are completely encased, and those intended for launches are so arranged that their centre of gravity is very low.

It seems strange that no effort has been made in this country to produce thoroughly efficient motors, for small power, at a reasonable price. The writer has from time to time urged manufacturers to make such motors for

him to meet his own requirements. The replies generally have been to the effect that there was no demand, and, therefore, to make such motors would not pay. It is a discredit to this country that, at the present moment,

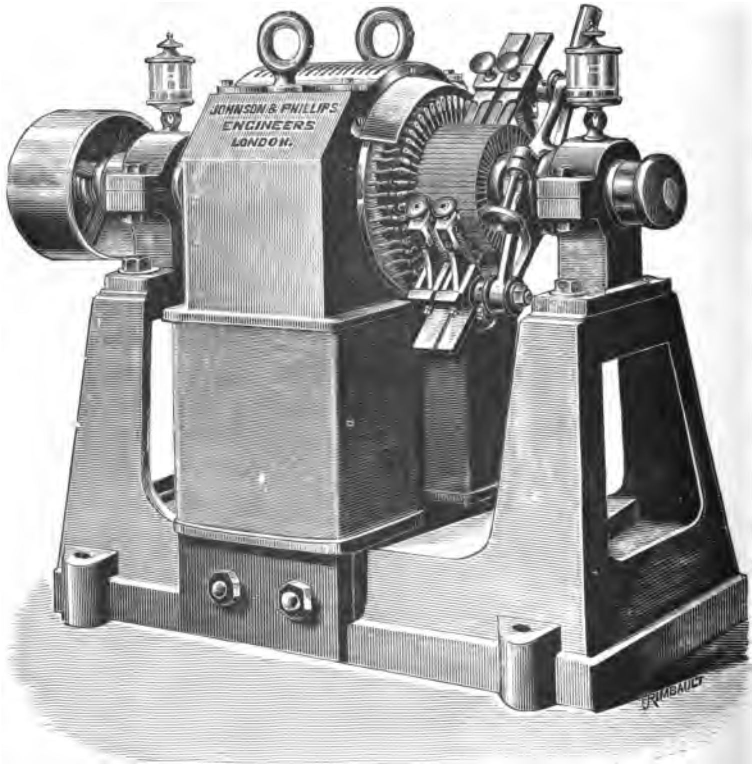


Fig. 31. –Kapp Dynamo.

the most satisfactory motors of this class come from America. The author's suggestions have been fully justified by the enormous sale of these motors from across the Atlantic. They are so largely used that it is thought

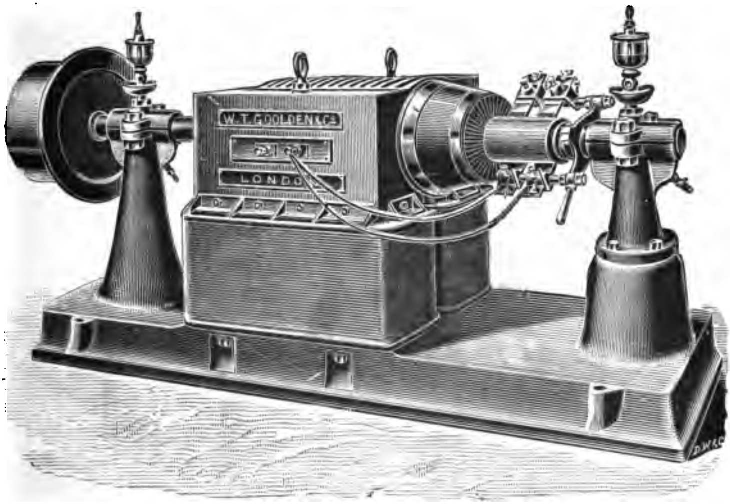


Fig. 32.—Goolden Dynamo.

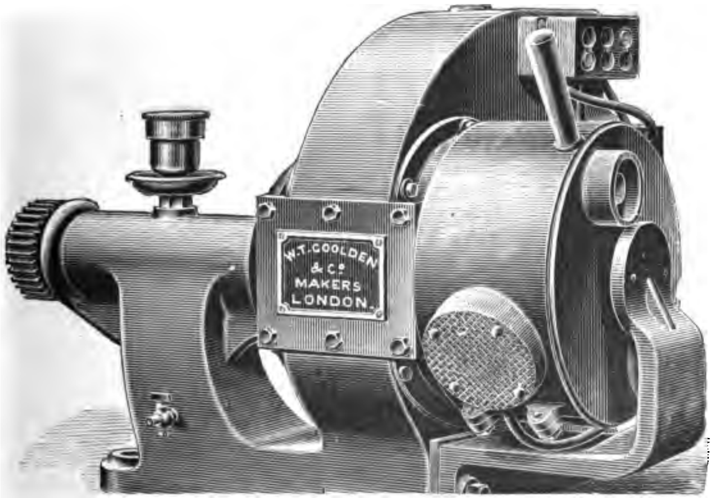


Fig. 33.—Goolden Dynamo for use in Mines.

advisable to give several illustrations of them. Those chiefly in use are made by Messrs. Crocker & Wheeler. On examination the apparatus will be found to contain nothing actually new in its construction. These motors depend for their success upon the fact that they are well and carefully made throughout. No small details,

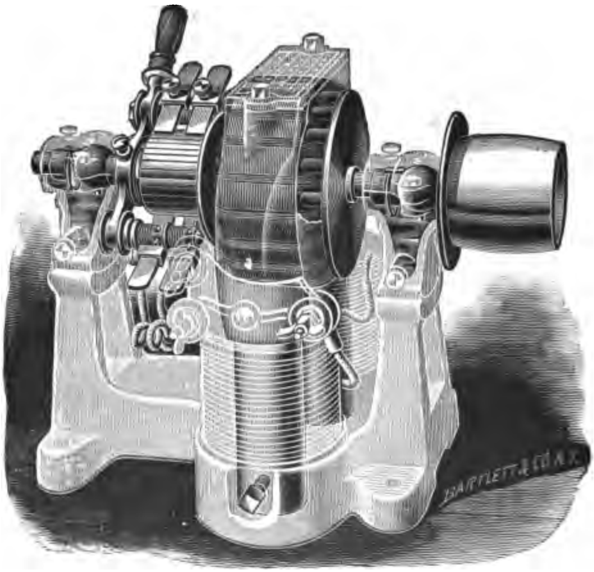


Fig. 34.—Diagram of Crocker-Wheeler Motor.

which may tend to convenience in use, are neglected, and the price is reasonable. Apart from these considerations, the apparatus is light and very fairly efficient. The General Electric Co. are the sole agents for Messrs. Crocker & Wheeler in this country, and the firm have had a hard task to meet the demand for their goods. These little mctors can be employed also as dynamos, if so desired; and the American firm

makes two modified forms, which are very useful for certain purposes; one form intended to give a constant current for arc-lighting, and the other for use as a direct-current transformer, raising the pressure of the current from 60 volts to 100 volts, or the inverse, or any other conversion of pressure that may be needed. Fig. 34 shows the motor, portions of which are represented as transparent in order that its construction may be seen.

Fig. 35 shows one-sixth horse-power motor, with wormwheel gear.

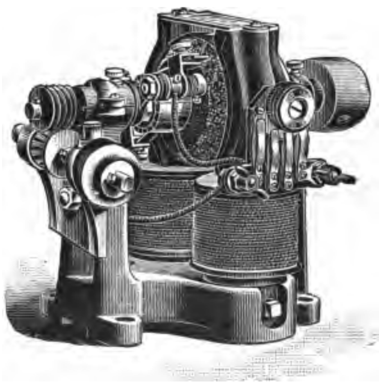


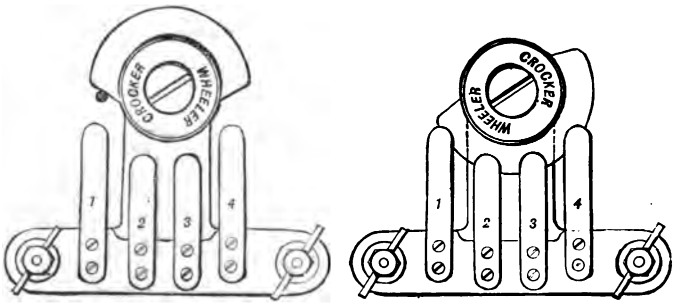
Fig. 35.—Crocker-Wheeler Motor.

The smaller sizes run from one-twelfth to one horse-power. They are generally shunt-wound, and a special form of switch is attached in order that the field-magnets may be excited before the current is passed through the armature. An enlarged view of the switch is shown in Fig. 36, in two positions. When the plates 3 and 4 only are joined, the field is excited; when the switch is turned further, then the current passes through the armature. In some instances these switches are modified so as to run the motor half or full speed, the winding of the motor being slightly varied for the purpose.

In Fig. 35 the switch will be observed at the side of the motor. The pole pieces are ploughshare-, or wedge-, shaped, in order to permit the machine to run

noiselessly. The speeds vary from 700 in the larger sizes up to 1,600 and 1,800 in the smallest.

Fig. 37 illustrates the type of plate affixed to each motor, showing the speed and current. At the present time there is also another figure impressed upon it, giving the voltage. It is to be regretted that such plates are not attached to all dynamos and motors.



STOPPED. RUNNING.

Fig. 36.—Crocker-Wheeler Type of Motor Switch.

In all but the smallest size of motor the bearings are self-oiling. The bearing standard is hollow and is charged with oil. Two loose rings, which pass over the shaft, dip into the oil; and in this manner the lubrication is effected. The details are well seen in Fig. 38.

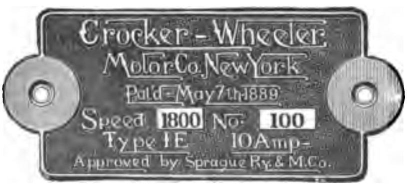


Fig. 37.—Name Plate.

In order to start the larger sizes of the motor, a very convenient form of resistance is employed. The switch is situated on the resistance case instead of upon the motor. This is shown in elevation and section in Fig. 39.

The details for connecting up are sent out with the motors and, therefore, need not here be referred to.

Other good makers of this class of machine include the Electric Construction Corporation and Messrs. Immisch. All the motors referred to work equally well as dynamos.

There are at present many of the high-pressure direct-current type of dynamo made for arc-lighting. The two which take the lead are made by

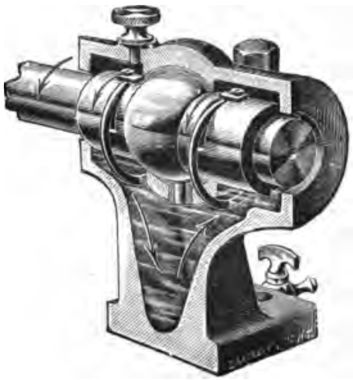


Fig. 38.—Detail of Self-Oiling Bearing.

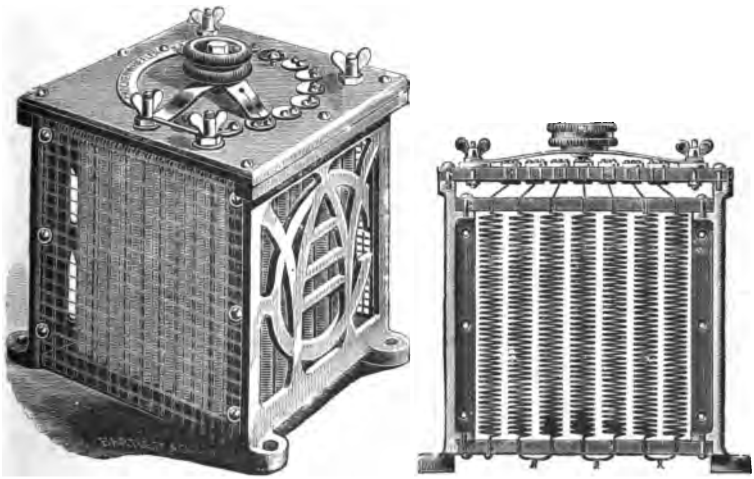


Fig. 39.— Crocker-Wheeler Resistance Box.

the Brush Engineering Company in England and by Messrs. Thomson-Houston in America. The armature

in the latter machine is spherical in shape. The Brush machine is shown in Fig. 40.

There are in the market many dynamos arranged to give a constant current, and which are intended for use with a "series system" of lighting or with traction.

A dynamo to give very heavy currents at low pressure is shown in Fig. 41; such a machine is used for electroplating, electric welding and smelting. The armature wires in this case are copper bars of large section.

For the production of an alternate current special machines are employed. They consist of two sets of

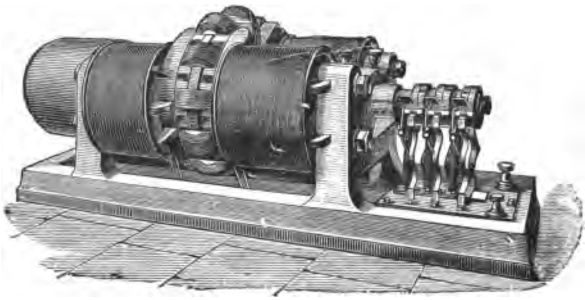


Fig. 40.—Brush Arc Dynamo.

magnets, each set arranged as a crown, the polarity of the magnets being north in one crown and south in the other. These magnets are now of the electro-magnet type, but the earlier makers used permanent magnets. M. de Meritens was one of the first to work in this direction. The armature, which is placed between the two crowns of magnets, consists either of a number of coils or partial coils, these latter being formed by bending copper strip or winding wire zigzag fashion. In some types the armature revolves, and in others the magnets, or inductors, as they are often termed, revolve. A crown of inductors therefore exists on each side of the

armature. Consequently, when a continuous current is exciting the electro-magnets, an induced alternate current is produced in the armature when rotated. The magnets and armature design admit of any number of modifications, so that the above description only covers one type.

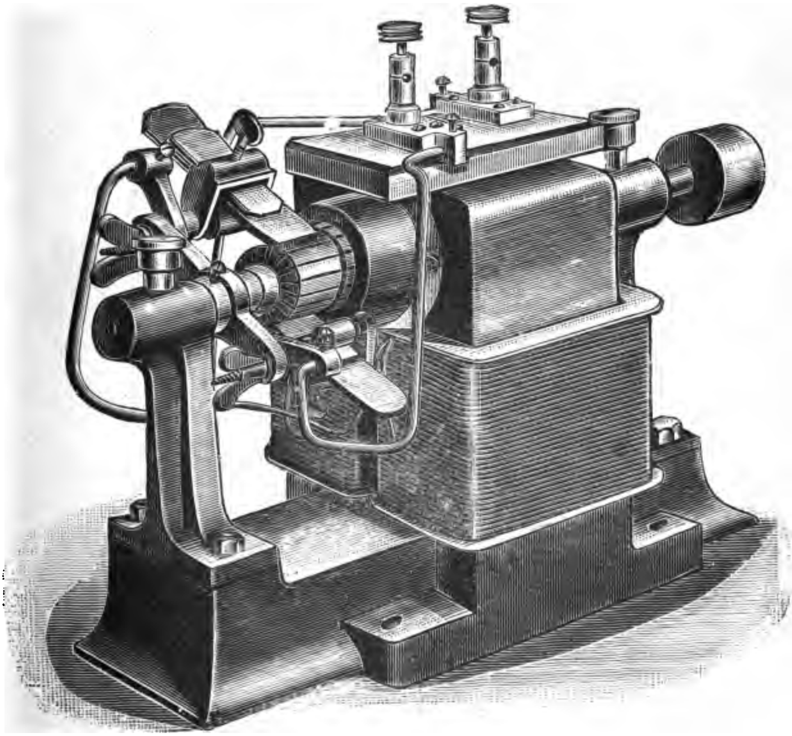


Fig. 41. – Plating Dynamo.

Those readers who wish to have a more detailed knowledge of dynamo-electric machinery would do well to study Professor Sylvanus Thompson's "Dynamo-Electric Machinery" and Professor Fleming's work on the "Alternate Current Transformer."

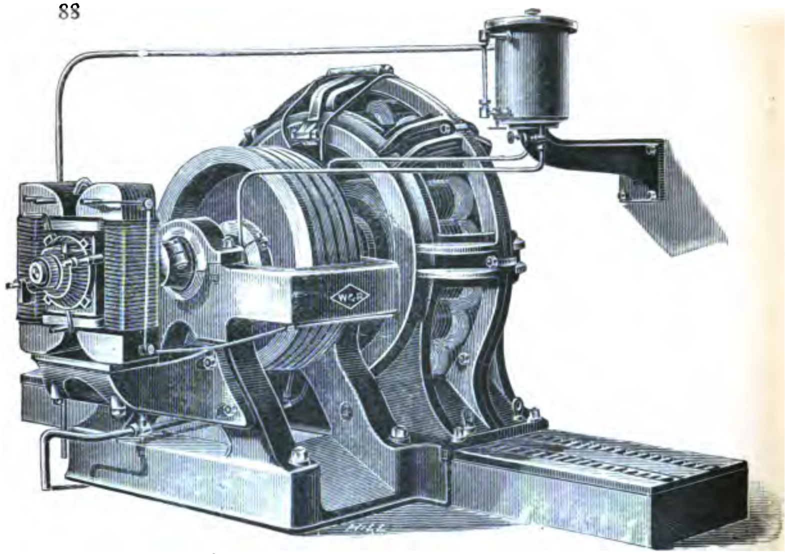


Fig. 42.—Ferranti Alternator and Exciter.

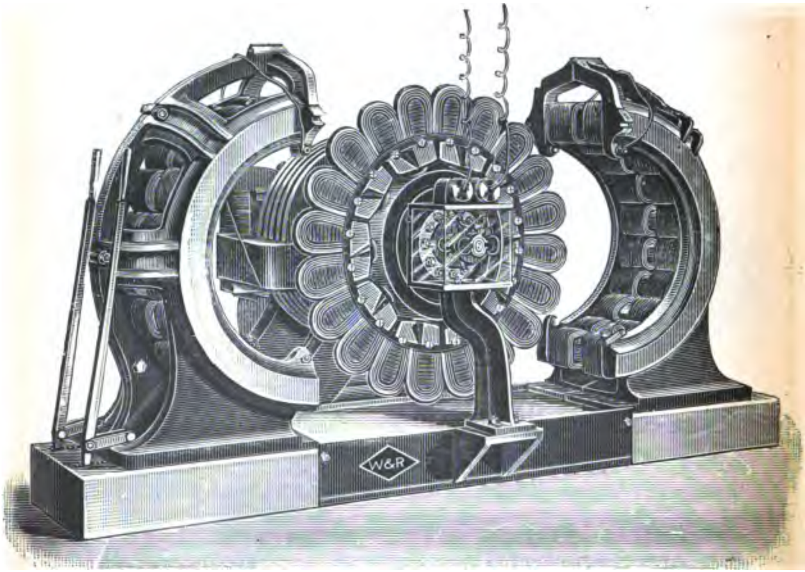


Fig. 43.—Ferranti Alternator taken apart.

Fig. 42 represents a Ferranti alternator, with the exciter—*i.e.* a small direct-current machine used to excite the inductors, on the same spindle as the armature. There is no iron in the armature.

Fig. 43 illustrates the same machine, with the inductor magnets drawn apart to give access to the armature for repairs.

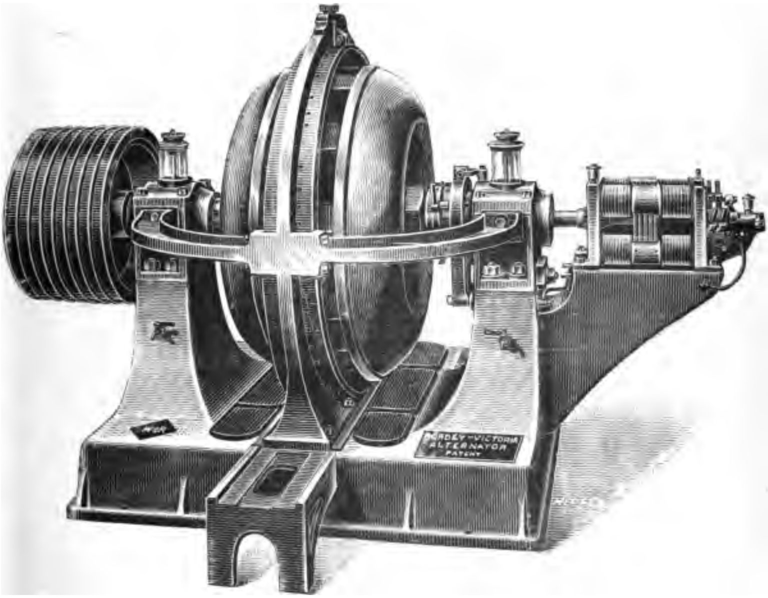


Fig. 44.—The "Mordey-Victoria" Alternator.

Fig. 44 shows a similar machine (with the exciter) of Mr. Mordey, and made by the Brush Co. In this case the magnets revolve while the armature, which contains no iron, remains stationary.

Figs. 45 and 46 illustrate the appearance of a Mordey armature, as seen from each side.

Fig. 47 shows the shape of Mordey's Revolving Magnets, with the circular winding in the centre.

The Thompson-Houston alternator has iron in the armature, and withstands the heaviest loads satisfactorily.

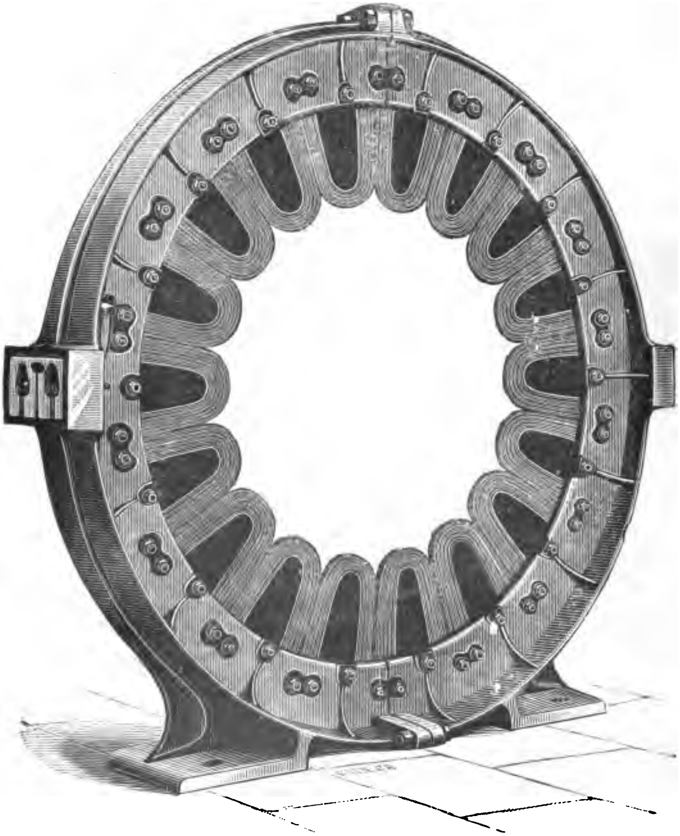


Fig. 45.—Mordey Armature.

Fig. 48 represents a Siemens alternator, with a separate exciter, the latter of the old pattern. There is no iron in the armature.

An alternator, unless it possesses sufficient self-induction to permit the machine to be short-circuited, without

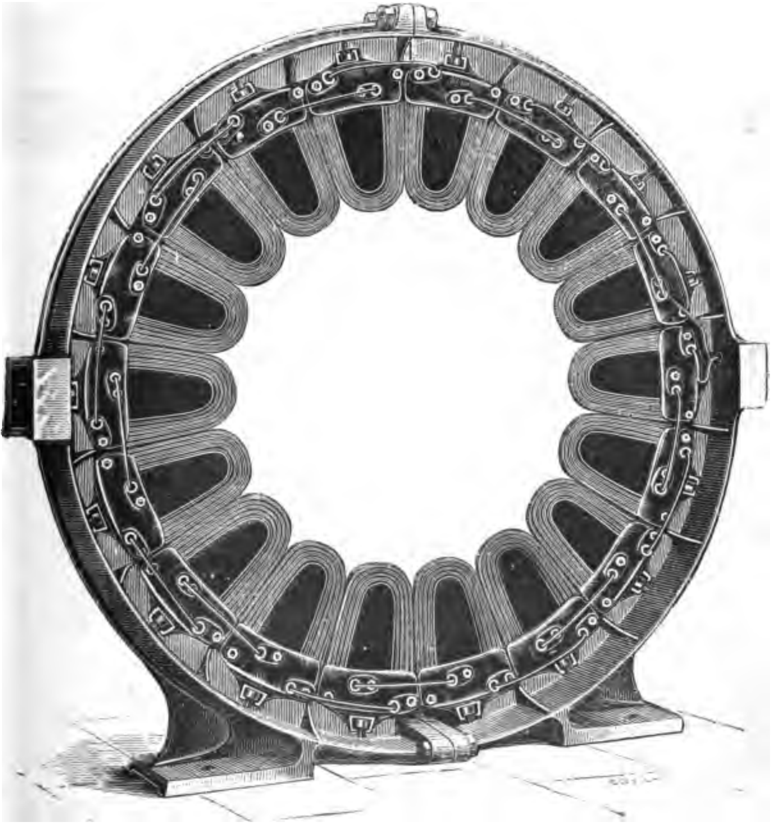


Fig. 46.—Mordey Armature.

injuring it, may be regarded as an unsatisfactory piece of apparatus for real hard work and sudden strains.

Two pretty little alternators are manufactured by Messrs. Pyke & Harris. They are particularly suitable for laboratory experiments. The weight of the

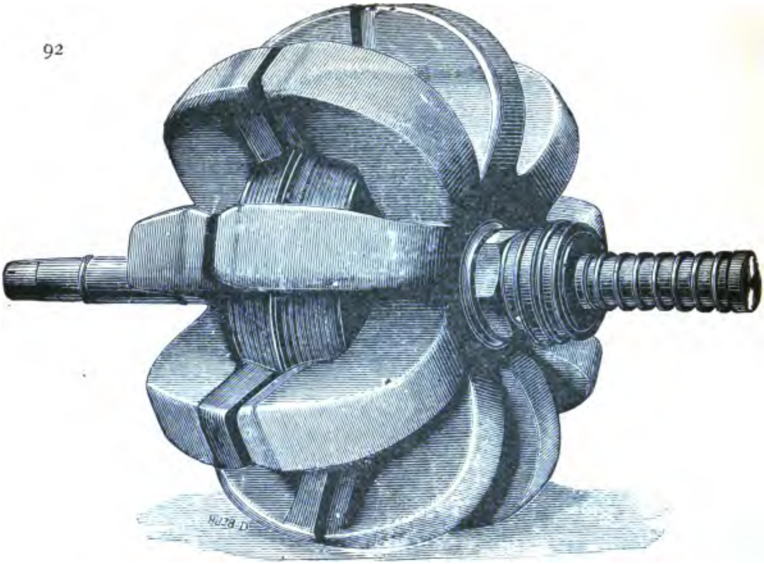


Fig. 47.—Mordey Magnets.

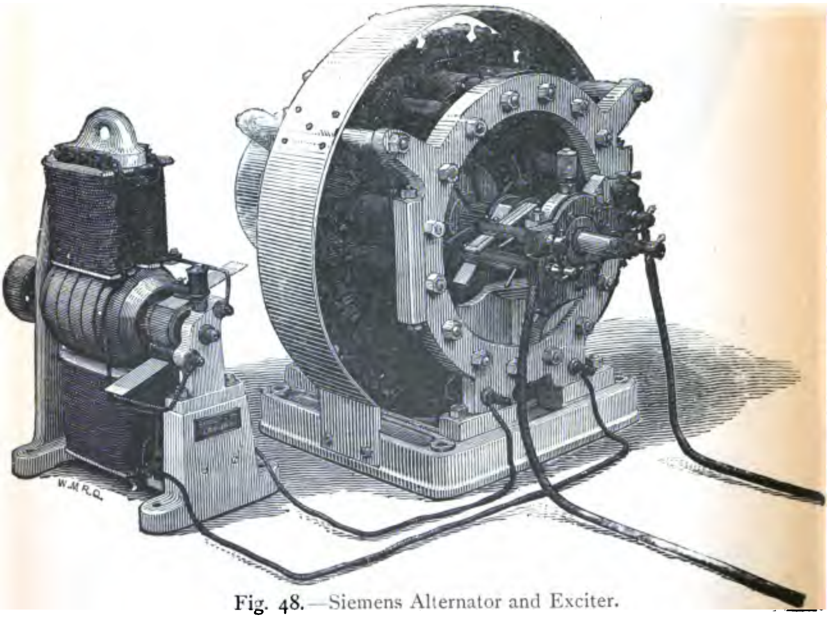


Fig. 48.—Siemens Alternator and Exciter.

small size is about 65 lb. and of the other 1 cwt. The same firm also makes these machines on a larger scale.

Fig. 49 is a view of the Laboratory alternator. It is made of a block of wrought iron, the place for the inductors being bored out true in a lathe. The revolving

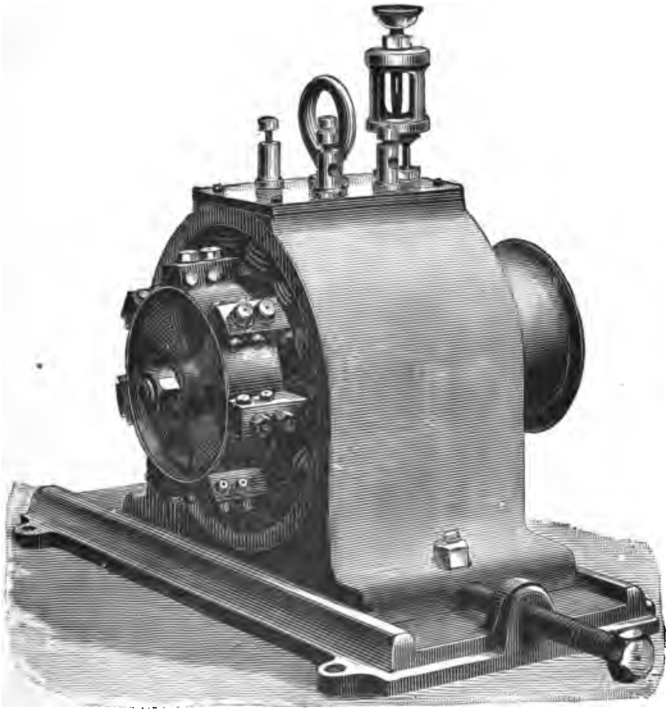


Fig. 49.—Pyke Laboratory Alternator.

portion is shown in Fig. 50 (J and J), and consists of a number of plates of soft iron bolted together and attached to a frame of gun metal. There is no winding on the revolving parts. The spindle S carries the framework C, to which the inductors are fixed, and at the other end the pulley P. It will be observed tnat

there is only one bearing; L is the cup to supply the oil, and a little tap exists at the bottom to draw off the waste oil. D is the winding which excites the inductors, and R and R_1 are coils forming a stationary armature; B shows the section of the wrought-iron carcase.

Fig. 51 is another section. B represents the wrought-iron block, as before; J, J and J indicate the inductors,

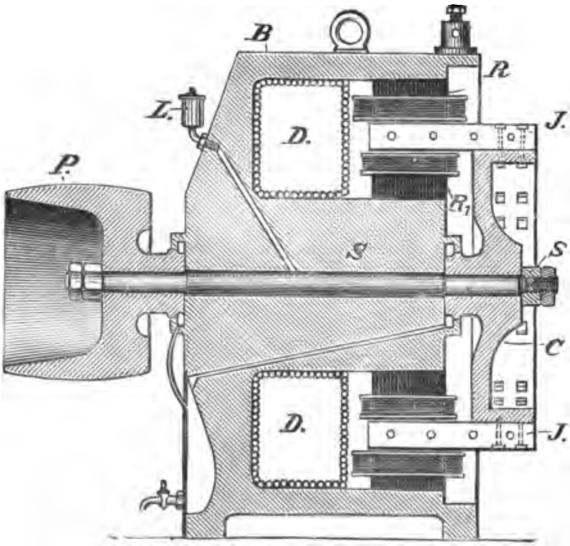


Fig. 50. - Pyke Laboratory Alternator. Section.

and F the armature coils. In these machines the frequency can be varied at pleasure within certain limits. The alternator of the large size can give 8 amperes at 250 volts for its maximum output, and that of the smaller size will give about 5 amperes at 100 volts.

Many fancy forms of alternators are made, which at some period may find their place in practical work.

Many persons are now experimenting with currents

having very high frequency, and high E.M.F.—Professor Ewing, Mr. Campbell-Swinton, Professor Crookes and others, including Mr. Pyke and the author. Professor Ewing has had a special machine built for him by Messrs. Parsons. Professor Crookes and Mr. Campbell-Swinton employ induction coils. Messrs. Pyke & Harris have constructed two special machines, in accord-

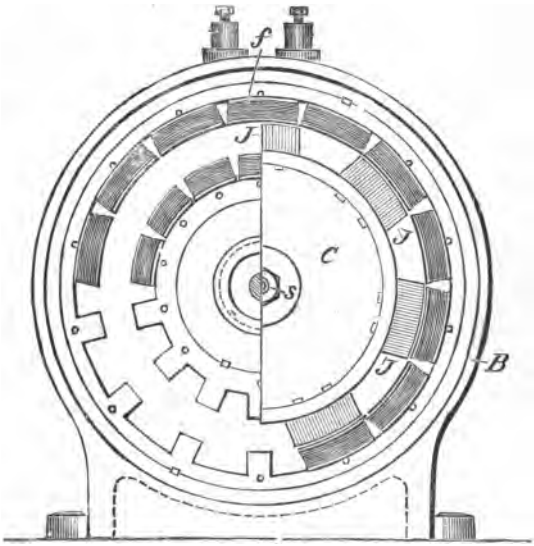


Fig. 51.—Pyke Laboratory Alternator. Section.

ance with the instructions of Mr. Pyke and the writer, for experiments in this line.

One form of high-frequency alternators on Mr. Pyke and the author's principle is shown in Fig. 52. In order to attain a high speed, two direct-current motors are employed, revolving in opposite directions, one motor rotating the inductor-magnets and the other the armature. Since this machine was made some improvements have been introduced.

Where the alternate current is used on a large scale, transformers are invariably used, these apparatus being capable of raising or of lowering the voltage of the primary current. They consist of nothing more than a modified form of ordinary induction coil, the wire on the primary coil being thin as compared with that on the secondary coil. Such a method of winding will give a lower pressure and a larger current on the secondary circuit compared with the pressure and current in the primary circuit. The inverse method of winding produces the opposite result. The well-known ordinary induction coil has an open magnetic circuit, and Mr. Swinburne prefers to make his transformers after that type. One is shown in Fig. 53. This apparatus he terms the "Hedgehog Transformer." At the present time the closed magnetic circuit transformer finds most favour, since, under varying conditions, it is more economical than the open magnetic circuit type.

Fig. 53.—"Hedgehog" Transformer.

Fig. 54 shows a Ferranti transformer, of the closed magnet type ; and Fig. 55 a similar type of apparatus of Mr. Mordey, made by the Brush Co.

All kinds of devices have been suggested in connection with dynamos of the direct, as well as of the alternating, type. A majority of the suggestions made at the present time are experimental, but there is one which is worthy of attention, if satisfactory commercial condensers can be made. It is an idea of Mr. Swinburne to excite the inductors without using an independent direct-current, condensers being employed for this purpose.

Fig. 52.—Salomc

No satisfactory alternate-current motor, available on all circuits, exists as yet. For large powers, the alternator, employed for the generation of the current, works well as a motor if put in motion before the current is turned into it. Any direct-current motor, with its iron well divided so as not to heat, will work with an alternate current, but not efficiently. Brown's motor works

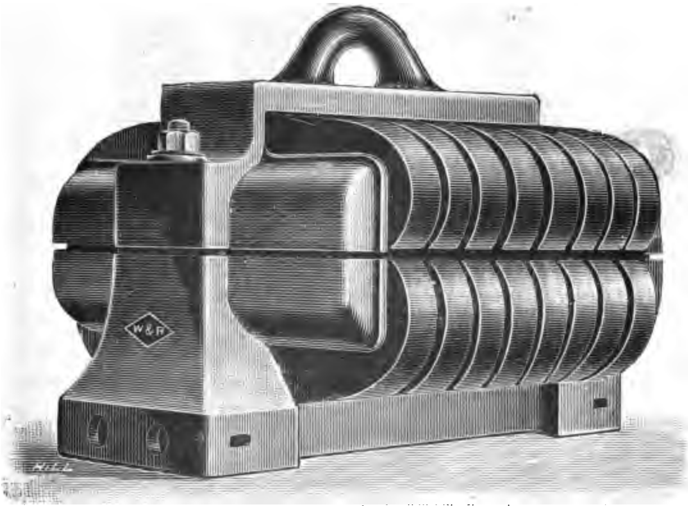


Fig. 54. – Ferranti Transformer.

satisfactorily with frequencies from 60 to 100; and in England, at the present time, the frequencies are usually about 100. Tesla has also devised a motor. The demand for an alternate-current motor increases daily, so that at any moment many satisfactory ones may be placed upon the market. Devices also exist for the conversion of an alternate current into a direct one. Some are satisfactory, and shortly we may expect to see some very simple piece of apparatus for

effecting this end. Ferranti's apparatus is one of the best machines at the present time for converting alternate into direct current. There are also direct-current transformers, which are modified motors, and must be kept in motion during the time they are acting.

Fig. 55.—Brush Transformer.

CHAPTER III.

INSTRUMENTS.

THE chief instruments required in an installation are the ammeter and voltmeter. In most instances both are made in the same way, the difference being simply in the resistance of the wire upon the instruments. The ammeter gives an indication of the quantity of current flowing through it, without sensibly lowering the E.M.F. The resistance of an ammeter must be very low, so that the fall of pressure in passing the current through the instrument may be reduced to a minimum; otherwise a considerable loss of power would occur by the use of this apparatus. In the voltmeter it is the reverse. Its resistance must be very high, so as to allow only a very small quantity of current to pass. The indications will be proportional to the quantity of current passing, and, therefore, to the pressure forcing it through. This instrument is connected, not in the course of one lead, as with the ammeter, but across the leads (in shunt), like a lamp placed in parallel.

The above remarks apply mainly to instruments which have coils of wire in their construction, but there are many that depend on other principles, and some of them will be referred to later.

The majority of these instruments may be divided under four heads:—

1. Direct reading.
2. The instrument must be set for each reading.
3. Direct reading, and result obtained by calculation.
4. Set for each reading, and result by calculation.

Then, again, all these may be divided into instruments that are dead beat and those that are not. When calculations are necessary, for convenience a table of reference is generally used.

The dead-beat direct-reading instruments are the most convenient, because the needle comes to rest at once, giving the correct reading on the scale in amperes or volts; but, as they are liable to become inaccurate, they require periodical recalibration. Some instruments must be placed far removed from currents and masses of iron. Each kind has its uses, and to obtain true readings several patterns should be employed for checking one another if no standard exists.

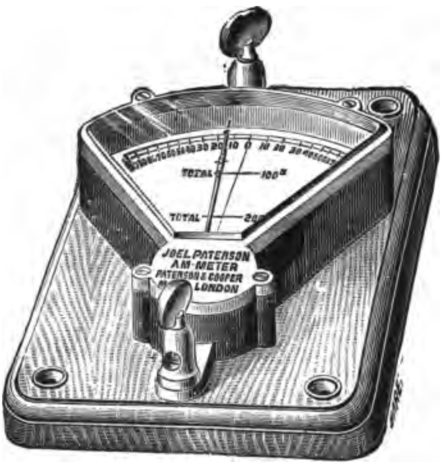


Fig. 56.—Joel & Paterson Ammeter.

Illustrations are here given of a few of the leading ammeters and voltmeters.

Fig. 56 represents a Joel & Paterson's pattern engine-house ammeter, giving approximately correct indications. It reads direct, but is not dead beat. Large currents flowing near this instrument affect the readings. Its

action depends simply on the current to be measured passing through a strip of copper, before which a permanent magnet, attached to a pivoted spindle, swings vertically. The needle is kept upright when at rest by a weight attached to an arm fixed to the spindle, and this spindle carries a long light pointer, which indicates upon the scale. Adjustment is obtained by increasing or diminishing the distance of the weight from the spindle. It is evident, therefore, that the principle of this ammeter depends upon the displacement of a swinging magnet against gravity, recalibration at times being necessary in consequence of the changes which may take place in the strength of the permanent magnet. This instrument is illustrated because it is the simplest possible form of ammeter, and is rarely used.

Fig. 57.—Dead-Beat Ammeter (Simple).

Fig. 57 shows an ammeter by Messrs. Paterson & Cooper; it is actuated by the current passing through a coil of wire, in the centre of which swings a permanent magnet carried upon a pivoted arbor. Around the whole is placed a horse-shoe permanent magnet, and between the poles of the latter the pivoted magnet swings. The spindle carries a pointer, as in the last case. This instrument is dead beat, because the magnet moves in a strong magnetic field. It is also direct reading and fairly reliable. Recalibration must occasionally be resorted to. The usual adjustments are found upon the instrument. It is to be regretted that this ammeter is no longer made in this form.

Fig. 58 is an improved form of the preceding pattern, suitable for experimental work. The coil is in this case subdivided into ten coils, and these can be placed in parallel or in series by means of the commutator seen in the figure. When the coils are in parallel each degree has ten times the value they have when in series. Formerly this instrument had a piece of iron placed against the poles of the permanent magnet for an armature, the idea being that by so doing the strength of the horse-shoe magnet would be more constant over a long period of time. Experience has proved this to be an error. Alterations in magnetism were soon produced by continually plucking off and replacing this armature, and Lord Kelvin has shown that a well "aged" piece of steel, when magnetised, will keep its magnetism nearly constant for a very long period. The expression "aged" is used to imply that the metal has been subjected to considerable rough usage, such as successive heatings and coolings, hammering, and the like. This form of ammeter was originally devised by Messrs. Ayrton and Perry. It will be noticed that there are three terminals shown upon the instrument—one marked P, one

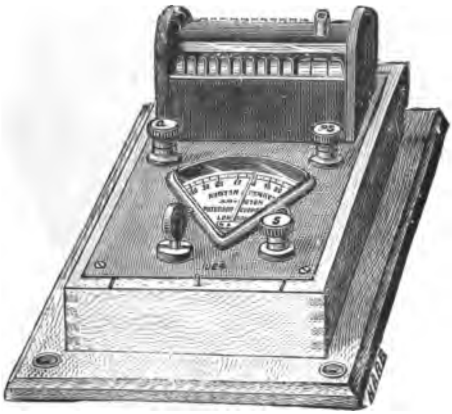


Fig. 58.—Dead-Beat Ammeter (Commutator).

S, one P S. For small indications of current terminals S and P S are used, and coils placed in series; otherwise, no current passes. For large indications P and P S are employed, and coils in parallel; P S, therefore, is a common terminal, P takes a large wire, and S is only capable of taking a small one. By this arrangement the passing of a large current through the instrument when the coils are in series, and thereby destroying them, is rendered an impossibility. The plug seen in the drawing is used for calibrating the instrument, and is in connection with a 1-ohm coil.

The following is the method of calibrating:—

In the commutator instruments the adjustment, by which the deflections are rendered direct, is made by moving the galvanometric coil from a stronger part of the field into a weaker part, or *vice versa*. The coil is supported by two screws, and by means of nuts it can be moved as above described. On unscrewing the base-board the magnet and coil of the instrument are exposed, and the adjustment can then be made.

To calibrate the commutator ammeter turn the commutator to series, and send a current from a standard cell of known E.M.F. through the ammeter, obtaining a deflection D. Pull out the 1-ohm plug; the deflection will now be reduced to *d*. If E is the E.M.F. of the cell in volts, then current $= E\frac{D-d}{D}$ for deflection D, and 1° gives $E\frac{D-d}{D\,d}$ amperes in series, or $10\,E\frac{D-d}{D\,d}$ amperes in parallel. The adjustment of the coil must be made until the desired value per degree is obtained.

To calibrate the simple ammeter, place it in series with a standard instrument having about the same

range, and let the current flow through both, adjusting pole screws of the former until the instruments agree. Then repeat for other values.

Many instruments are to be found in the market which are similar to the above ammeter in principle,

Fig. 59.—Ayrton and Perry's Magnifying Spring Ammeter.

but the permanent magnet is replaced by an electromagnet. Apparatus of the above kind are convenient for daily requirements.

Fig. 59 shows Professors Ayrton and Perry's long-range ammeter, the makers being Messrs. Latimer Clark and

the Acme Electrical Works. In this a small piece of iron is sucked into a solenoid against a special form of spring, more or less as the current is stronger or weaker. The spring consists of a spiral ribbon of phosphor bronze coiled edgewise, and this at one end carries a needle which passes over a dial. For any extension of such a form of spring a large rotary movement is given to any point upon it. In the base a compass needle is shown,

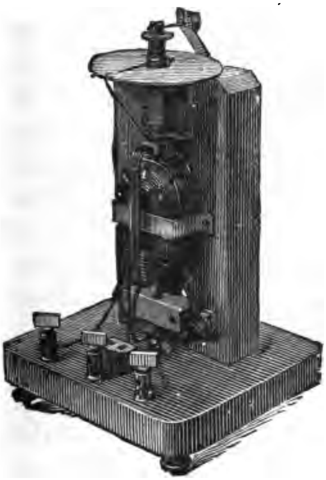


Fig. 60.—
Siemens' Dynamometer.

Fig. 61.—Siemens' Dynamometer (Best Form).

which is employed to indicate the direction of the current. This instrument is not dead beat, but is direct reading, and requires occasional recalibration. All the instruments described are only suitable for direct currents.

Figs. 60 and 61 illustrate Siemens' dynamometer. Fig. 60 is the ordinary form and Fig. 61 the better class of instrument, but the details are the same in both. Here the current to be measured passes successively through a

fixed coil and a movable coil. The ends of the movable coil, which consist of one turn of thick wire, dip into mercury cups to enable the current to traverse it. This movable coil is suspended by a filament, which is surrounded by a spiral spring, one end being attached to a milled head carried by the frame of the instrument and the other to the coil. The latter has attached to it a pointer which indicates upon a circular dial marked in degrees. This pointer has a restricted play between two pins fixed to a dial, which can be well seen in Fig. 60. The end of the suspension thread passes free through a milled head to a point of support. It is evident that, if the pointer of the movable coil indicates zero on this scale, it will, on passing a current, become deflected and move towards one of the set pins. If the current passes in a right way, this deflection will be to the negative side of zero. In order to take a reading the milled head must be turned till the pointer is brought back again to zero. By doing this the spiral spring receives a torsion, and the amount of this measures the current passing. The needle attached to the milled head enables a reading in degrees to be obtained of the amount of torsion which has been given in any particular case. If the value in amperes is known for the first degree of torsion—and call this A—then the value for any other reading will be the square root of the angle of torsion in degrees multiplied by A. The instrument may be marked for direct reading if desired, but generally it is issued with a scale marked in degrees and a table of reference to save time in making calculations. It will be observed that for every reading a fresh setting is required. Since the strength of the spiral spring is very constant for a long period of time, these

instruments are very reliable; and because this ammeter contains no iron, it can be employed in connection with alternate currents. When not in use it is desirable to free the spring from strain by turning the mill-head so that its needle, as well as the pointer, stands at zero. The instrument possesses the necessary adjustments and a means of relieving the filament from the weight of the movable coil when out of use. There are usually two fixed coils, one of thick wire and one of thin, so that the instrument may give larger indications for small currents when required. Hence the reason for the three terminals shown on the base, the centre one being common to the two coils. Clearly each coil has a different constant. To give a practical idea of the value of the constants: in electro-dynamometer, No. 2,081, for the thin wire, the value of a reading $= \sqrt{}$ angle of a torsion x 0·9392; and for the thick wire $\sqrt{}$ angle of torsion x 3·176. These instruments require to be levelled before using.

If the setting back to zero after a reading is not resorted to, a permanent "set" is given to the spring. This can be corrected by a special adjustment.

Cunynghame's voltmeter is a portable form of Siemens'. It is very compact, and the method of reading is similar.

Fig. 62 illustrates Lord Kelvin's magnetostatic current meter. In principle it resembles somewhat Joel & Paterson's engine-house meter, but is far more beautiful in design, and it consists of a system of magnets suspended in the centre of a uniform magnetic field. The pointer and magnetic needle are upon a shaft supported by a jewelled centre, on an iridium point; and the dial is, therefore, horizontal.

A short distance below the dial, and encircling the case, is a pair of permanent magnets ; and just beneath these, the case is encircled by a second similar pair. In each system, like poles face one another. Each of these two permanent magnet systems is carried in a frame capable of rotation, and by varying the relative position of one set of magnets to the other set, the value of the dial

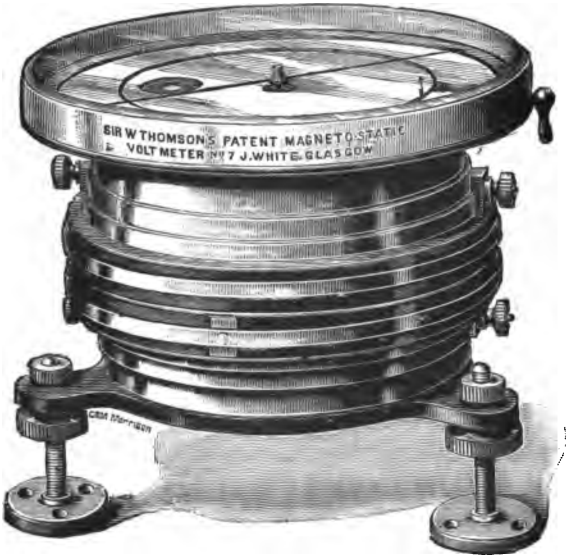


Fig. 62.—Kelvin Magnetostatic Instrument.

divisions is altered. If unity be the maximum value of one division, then 0·1 will be the value of the division when the magnets are rotated to a position for reading the minimum value. The instrument has a needle-checker, which can be used also as a lifter to render the apparatus portable. Levelling-screws also exist. This ammeter is a very convenient instrument in a laboratory,

on account of the large variations that may be given to the value of the scale division. The scale is a tangent scale, and is graduated for direct reading, the milli-amperemeter reading from 0·3 to 300 milliamperes, and the amperemeter from 0·3 to 300 amperes. These are the most useful sizes, although others are made. The

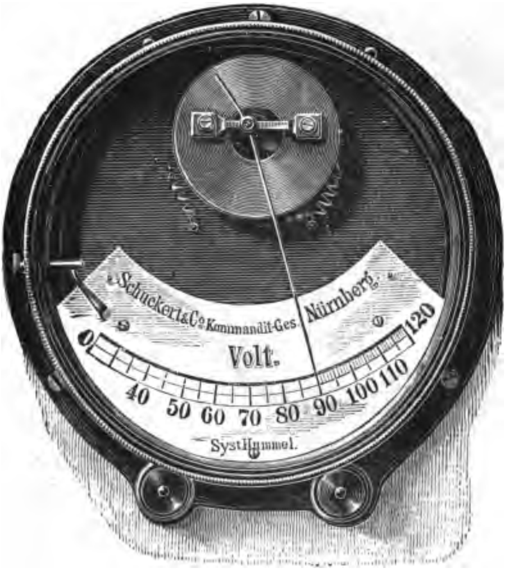


Fig. 63.—Schuckert's Ammeter.

division, by means of a standard instrument, can be made to read any desired value, this being effected by altering the positions of the permanent magnets outside the case.

It will be observed that the current passes in and out, by conductors placed one above the other. This current meter is not dead beat, but can be made direct reading by adjustment in the way mentioned, and needs occa-

sional calibration. This instrument is only for use with direct currents.

For measuring alternate currents, there are many instruments available for direct currents which cannot be used, since all iron in alternate-current instruments must be greatly subdivided, and the presence of a permanent magnet is not admissible. But instruments suitable for alternate currents may be employed with direct.

Fig. 64. Evershed Ammeter (Large Size).

Fig. 63 shows Schuckert's Ammeter. It is of foreign manufacture, but a good instrument for general purposes. It may be termed a "gravity" instrument. The reading is direct, but not dead beat.

Figs. 64 and 65 illustrate the large and small size ammeters of Mr. Evershed, the makers being Messrs. Goolden. They are compensated for hysteresis.

The remarks made in respect to Evershed's instruments apply equally to those of Messrs. Nalder. The two instruments referred to are suitable for alternate currents,

All alternate current instruments should be calibrated with currents having the same frequency as that in the mains upon which they will eventually be installed.

Many new forms of ammeters have appeared, a favourite kind consisting of a solenoid, through which the main current is passed, and in which a piece of soft iron is suspended in such a manner that it is drawn into the solenoid to a distance proportionate to the current flowing through the coil, a needle being so connected with this core as to indicate in amperes upon a scale; the iron being counterpoised by a spring or weight.

Fig. 65.-- Evershed Ammeter (Small Size).

The author, after many years' experience with ammeters in no way limited to any particular form, has come to the conclusion that, for continuous currents, for a cheap and trustworthy instrument there is not one to excel the inexpensive form of permanent-magnet instruments made by Messrs. Paterson & Cooper. He has found no appreciable variation in the reading of instruments which have been in continual use for six or seven years. The advantages they possess over other forms are very great, and may be stated thus:—

1. They are dead beat.

2. The scale starts at zero and reads right up to the limit.

3. The scale is fairly open and the divisions are equal.

4. They are sensitive.
5. Not affected by currents or iron in their proximity.
6. Most easily adjusted when required.
7. Simple in construction.
8. Indicate the direction of the current without a supplementary needle, which property is especially useful when employed with accumulators; showing at a glance whether the current is going in or out of the battery.

Finally, these instruments are probably cheaper than any others in the market.

When a number of them are placed close together, they should be calibrated in position, or, when this is not convenient, the makers can calibrate them, placed close together in the same position as that in which they are intended eventually to be used.

The instruments are now made, in an improved form, in brass cases; on the permanent-magnet principle, as well as on the electro-magnet principle—*i.e.* the magnetic field is made by the current to be measured. The author prefers the permanent-magnet type in every way.

There are many other current-measuring instruments (which, however, might be termed indicators rather than measuring instruments), such as that of Mr. Henry Crookes, dependent upon the temperature to which a piece of metal is raised and shown by means of his heat-indicating paint. There are also others, which depend upon temperatures and chemical principles, but they are not employed for practical work.

The chief forms of ammeters having been touched upon, attention may now be directed to a few of the leading forms of voltmeters. The ordinary form of

these instruments is similar to that of the majority of the ammeters described, with the sole distinction that their resistance is very high in those cases where the current passes through the instrument, so as to permit only a very small amount of current to pass, and to give a large indication upon the scale for very small variations in the current passing.

It is usual to adjust the resistance upon these instruments, so that a current may pass not exceeding one-twentieth of that which would be required for a 8 candle-power glow-lamp suitable to be employed upon the circuit whose E.M.F. the voltmeter is intended to measure. Frequently its resistance is twice and thrice this amount. Consequently, if a voltmeter coil is wound with wire of sufficient length and size, the current may constantly pass through it, without producing too much heat, and the current employed to obtain a continual indication is very small.

Fig. 66.—Siemens' Voltmeter.

Messrs. Paterson & Cooper make a voltmeter similar in principle to their ammeter just described. There is also a voltmeter on the same principle as that employed in Ayrton and Perry's magnifying spring-ammeter. Siemens' voltmeter is shown in Fig. 66.

The readings in this instrument are taken by a method similar to that of the dynamometer already described. But its principle depends upon the current passing

through suitably placed coils acting on a suspended permanent magnet in connection with a spiral spring. Before taking a reading the instrument must be rotated upon its base until its suspended pointer comes to zero. There are the usual adjustments. A box of resistances is always employed with this voltmeter, and the setting of

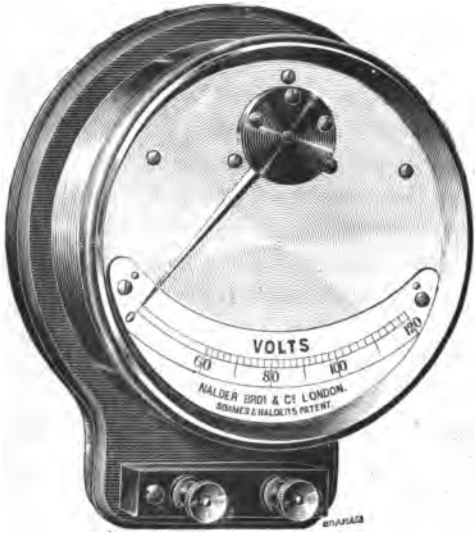


Fig. 67.—Nalder Brothers' Voltmeter.

the plugs alters the values of the divisions upon the scale according to the wish of the operator. The graduation of the scale is such that no table of reference is required. The instrument is not suitable for alternate currents. The pressure of these latter currents may be measured by a special form of dynamometer.

Messrs. Nalder's voltmeter (Fig. 67) is also very similar in appearance to their ammeter, and can be employed with alternate currents.

All makers of instruments manufacture some special form of voltmeter for alternate currents, as well as direct, in the same way as they do with ammeters. In a few instances, manufacturers do not produce two forms, but send out one form of instrument which is suitable for both types of current.

The Kelvin magnetostatic milliamperemeter in conjunction with resistance coils can be employed as a voltmeter, and the divisions on the scale may be read from one-fifth volt to two volts.

This instrument, although exceedingly accurate, requires calibration from time to time.

Fig. 68 is a general view of Major Cardew's voltmeter.

Its principle depends upon the expansion of a delicate wire made of fine platinum silver, having a diameter of 0·0025 inch. By means of a spring this wire is kept in a state of tension when cold, as well as when it is hot and expanded during the passage of a current. It is evident that, if this wire were passed over a pulley, the latter would rotate for any change in the length of the wire; and if the pulley carries a pointer over a scale, measurements of the variations in the length of the wire become possible. These indications are proportional to the temperature of the wire. The temperature of the wire depends on the current, and the current on the pressure, so that the readings are proportional to the pressure. Such is the principle of the instrument. The fine wire has a very great length, and to make this instrument more compact it is carried over a series of pulleys supported on rods, up and down, enclosed in a metal tube. The tube keeps draughts away from the

heated wire, which would render readings impossible. The length of the rods varies with temperature, and in some instruments they are built up of different metals and in such a way as to act like a compensated pendulum. There is inside the case a fuse to protect the wire. The mechanical indicating portion is very similar to that of an aneroid barometer. An adjusting screw

Fig. 68.—Cardew's Voltmeter (General View).

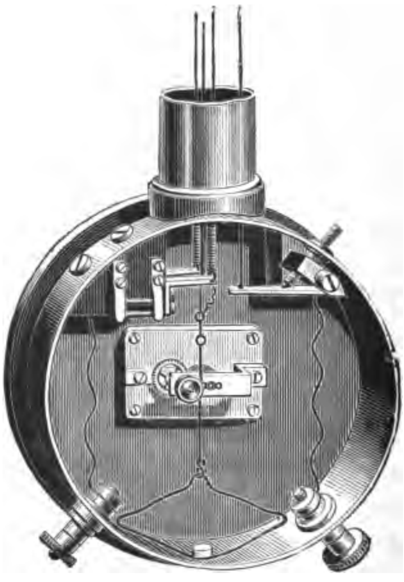


Fig. 69.—Cardew's Voltmeter (Interior View).

for obtaining true zero, and for calibrating, passes through the case, and is seen in Fig. 69, which is a view of the interior of the case. Fig. 69 is the view as seen from

the back when the cover is removed, and for the want of space the long tube is not shown.

A resistance-box is employed when the instrument is used for reading high E.M.F. Since there are no magnets or coils in the instrument, it may be read accurately near currents and masses of iron. This meter is almost dead beat, and very sensitive. There have been many improvements recently made with the view of obtaining the greatest accuracy, and an improved method of replacing the fuse, when needed, without the slightest difficulty; whereas, in the original forms the task was a most difficult one, owing to the fineness of the fuse wire. The steadiest readings are obtained when the tube is placed horizontally, since up and down currents of air, within and outside the tube, are avoided; the scale naturally being shifted to suit this position. If a Cardew voltmeter is always employed to read at a small range of its scale, it can be completely depended upon, but is rarely correct over very large ranges. Major Cardew says that this must arise from faulty construction in the instruments, but it is difficult to decide whether it is due to this cause or to the fact that, when the wire is generally expanded to a definite length, its proportional lengths for other temperatures become altered in the same way as mercury does in a thermometer. The current, direct or alternate, may be kept on continuously, and the indications are dead beat.

In Ayrton and Perry's hot-wire voltmeter the principle is similar to that of the Cardew, but it is much more compact in form. Variations in the length of the wire, the ends of which are fixed at each end, are measured by the sag, which is taken up by a spring and

measured upon a dial by means of one of their special forms of spiral spring.

The new form of Ayrton and Perry's hot-wire voltmeter is simple in the extreme. The arrangement consists of a stretched wire or carbon filament under torsional strain, which carries a pointer indicating upon a scale. When the wire is heated by the passage of the current, the twist in the wire or filament becomes less and the pointer indicates the fact. In this way the E.M.F. can be measured.

It is but fair that the author should mention that some years ago Major Cardew devised this very same form of apparatus.

The readings were taken by means of a mirror, after the manner of a reflecting galvanometer.

Messrs. Ayrton and Mather have an electrostatic voltmeter on the same principle as that employed by Lord Kelvin. Mr. R. W. Paul is the maker. One is also made by Mr. Swinburne.

Lord Kelvin's "Marine Voltmeter," which is equally suitable on land, and can be employed with any type of current, is shown in Fig. 70.

The scale is horizontal, but by placing behind it a mirror inclined forward at an angle, the scale is seen as in the figure.

The instrument consists of a stretched piece of platinoid wire, which carries a small oblate of soft iron, situated in the centre of a solenoid of fine copper wire. Fixed to this piece of iron there is a pointer which indicates on a scale. Resistances are used in connection with this instrument in order to vary the value of the divisions upon the scale, as may be desired. Its principle is that the oblate tends to rotate its equatorial

plane parallel to the lines of force in a uniform magnetic field.

The pointer is fixed to the oblate in such a position that, when pointing to zero upon the scale, the equatorial plane of the oblate is inclined about 45° to the lines of force of the solenoid. To obviate disturbance from outside forces, the solenoid has a massive tube of soft iron around it, cut away at one part to permit the pointer to pass through and indicate on the scale outside the case. To stop the vibrations of the needle, when taking a reading, an ingenious checker is provided. The necessary adjustments are found upon the instrument. There is also a reversing key. It may be left with the current continuously on. In these voltmeters the resistance is about 1,000 ohms, when employed for measuring 100 volt currents.

Fig. 70.—Portable, or Marine, Voltmeter.

This voltmeter appears to alter its zero slightly in the course of time, a variation due probably to changes taking place in the suspension wire. The adjustments on the instrument permit of the zero being reset.

These remarks apply to all Kelvin instruments, where the moving portion or portions are suspended. Marine ampere meters are made upon the same principle.

Instruments exist for indicating watts—*i.e.* volt-amperes, some of which are made for reading at the time, whilst others are self-registering. These are termed variously "watt-, erg-, power-, and horse-power-, meters." In all cases the indication shown at any moment is the product of the amperes passing through the instrument by the pressure of the current. They are constructed on more than one principle. To give an idea of how the result may be produced, one of the methods may be described.

If Siemens' dynamometer were to have the stationary low-resistance coil replaced by one of high resistance and connected to the mains after the manner of a volt-meter, the main current passing through the movable coil as usual, the pointer would register watts. The scale may be marked in two ways: one requiring a table of reference, and the other to read in watts direct. In setting up this instrument, it must be so placed that the pointer marks zero upon the scale. Since for direct currents these results can always be obtained by multiplying the amperes by the volts found by the readings of an ordinary ammeter and voltmeter, which exist in all installations, watt-meters are rarely employed in this case.

But for alternate currents, as the instruments for reading pressure do not indicate true volts, the readings must be multiplied by some constant. When the curve is a sine curve, or one approaching to this form, the multiplier is 1·2 (*i.e.* $\frac{1}{\sqrt{2}}$).

A watt-meter is essential for measuring the electric

energy in the case of alternate currents, since the readings require no further correction.

Lord Kelvin's instruments have already been referred to, but a chapter on this subject would be incomplete unless it included a fairly full description of his standard instruments.

Lord Kelvin is a man who never attacks a subject without producing an accurate and a perfect result. At the present day his standard instruments are regarded as approaching perfection as near as it can possibly be attained. These tributes are often given to the productions of men who have a great reputation, but when experience is brought to bear upon their labours, it is not unfrequently found that several of their devices fail in some point or other. A long experience of the instruments now referred to has shown that they issued from the laboratory at the very first in the most perfect state possible, a circumstance which is exceedingly rare. The various instruments have undergone changes in detail, but their principle remains unaffected; and those persons who possess the latest form of them find that the instruments are not one whit more accurate than those which first saw the light. No higher compliment could be paid to a scientific worker than is conveyed in these remarks, which are by no means limited to the writer, but indicate the consensus of opinion among men of science in the present day.

There is probably no high-resistance coil which will withstand a current passing through it continuously year after year. Such, at least, is the author's experience.

Some point in the coil always gives way; whether due to heat or corrosion is doubtful, but when an exami-

nation is made of a very large number of coils which have broken, the place of breakage, in almost every case, shows signs of corrosion. The Cardew voltmeter will often bear the current on for very long periods, but eventually, in the majority of instances, the fine wire breaks.

No one will deny that a continuous reading of E.M.F.

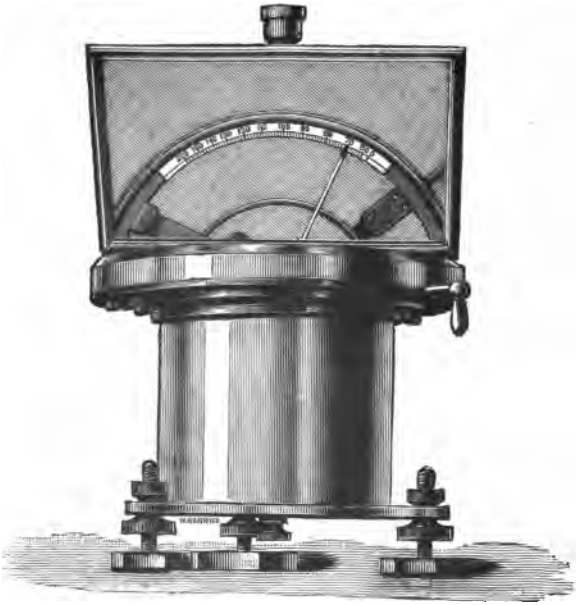


Fig. 71.—Multicellular Voltmeter.

is a great convenience, and the appearance of Lord Kelvin's multicellular voltmeter should be welcomed by all.

To-day a large number are in practical use, and since there is no loss whatever, no chance of a short circuit, no coil to get hot or break, no temperature corrections to make, currents flowing near do not affect the reading;

neither do magnets nor masses of iron, interfere, nor alternate currents create errors by self-induction ; and as there is also accuracy of reading, every advantage

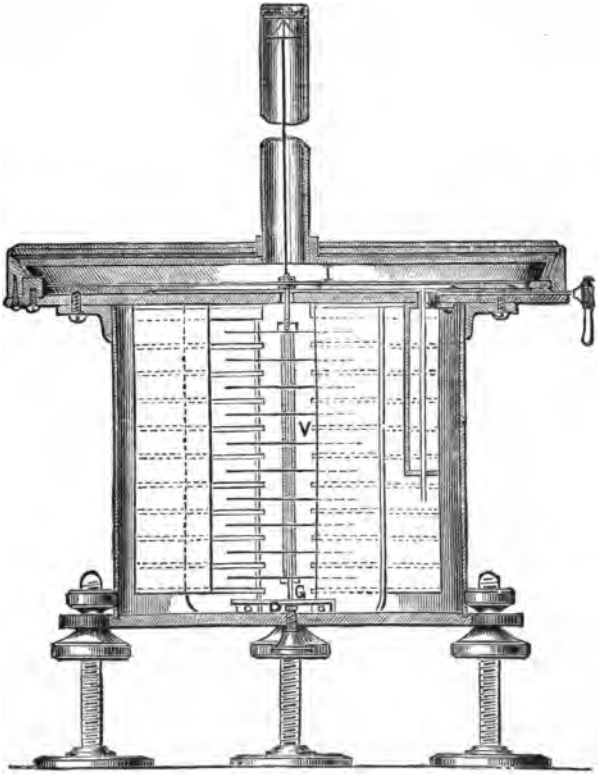


Fig. 72.—Multicellular Voltmeter (Vertical Section).

presents itself. In setting to zero it is necessary to cut one or both the connections from the main circuit and to short-circuit the instrument, in order to be sure that the two portions of the apparatus are at the same potential.

A suitable key exists upon the instrument for this purpose. The readings are in volts direct.

A multicellular voltmeter is shown in Fig. 71. It is practically an air condenser, the outside case is a cylinder of brass, and in the illustration the scale is seen by means of a mirror placed on the top. The instrument

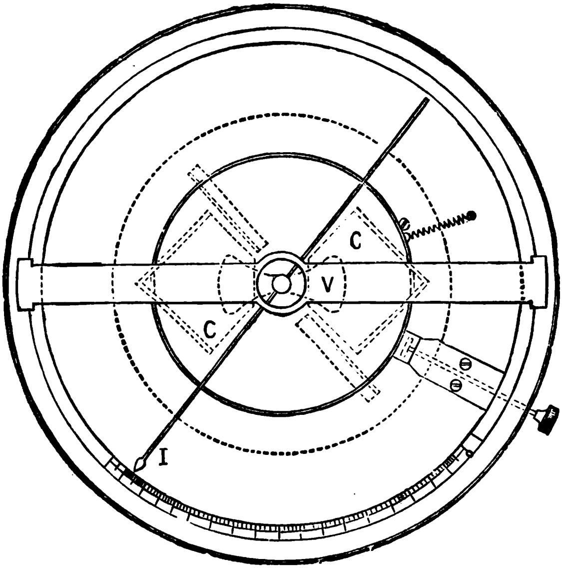


Fig. 73.—Multicellular Voltmeter (Horizontal Section).

may be better understood by looking at the vertical section in Fig. 72.

In the vertical section it will be observed that the brass case carries, on two opposite sides, a number of plates which may be termed "quadrants." These are now made triangular in form and may be seen in Fig. 73, marked C. In the centre there is a vertical spindle, which carries a number of vanes, indicated by

V, and kept in place by distance-pieces (see Fig. 72). One vane is situated midway between every quadrant. The vanes and quadrants are parallel to one another. The vane-spindle is suspended by an iridium-platinum wire to the top of the tube, as shown in Fig. 72. The horizontal pointer is attached to the top of the spindle, and consequently must move with the vanes, the iridium-platinum suspension wire being attached above this. The little mechanism shown at G and D, in Fig. 72, are there for the purpose of rendering the instrument portable when desired, by screwing up a milled head which is seen below the case. This done, the suspension wire is relieved and the spindle clamped.

To the upper end of the spindle is attached a small "coach spring" (not shown in the figure), and from this the suspension is made. Consequently, if the instrument is placed upon a table roughly, the suspension wire is not broken; the spring expands, permitting the vane-spindle to receive the blow upon the guard-stop at the bottom of the case. The spindle also is so restricted that under no conditions can the vanes come into contact with the quadrants. Naturally the vanes are insulated from the case. The indicator pointing on the scale is seen in Fig. 73. In the same illustration is seen a ring, which can be moved by a little milled head projecting beyond the scale case. This portion forms a checker, as well as a support for the needle, when the apparatus is being carried from place to place. The dotted lines forming two small oblongs, shown in the same illustration, represent the sections of two vertical plates to which the quadrants are directly attached. These are called the "repelling-plates," and they so act as to limit the movement of the vanes. In order to set

to zero, the upper part, to which the suspension wire is attached, consists of a head which can be turned. In the most recent form of this instrument the lower end of the vane carries a little disc, which hangs in a small pot of petroleum oil, that renders the readings fairly dead beat. There is also added a worm-wheel torsioned head at the top of the instrument for setting the zero. Levelling screws exist for setting up the instrument, also a key for short-circuiting the vanes and quadrants, when the zero is being adjusted. This switch cuts one of the leads previous to short-circuiting. In recent instruments the checker ring is dispensed with, because the oil dash-pot is added.

The principle of the instrument is that, when the respective mains are attached to the quadrants and vanes, any difference of potential will cause the vanes to cover the quadrants, and the greater the potential the more will the vanes move to cover the quadrants; or, as it is usually stated: "The movable plates tend to move so as to augment the electrostatic capacity of the instrument, and the magnitude of the force concerned in any case is proportional to the square of the difference of potential by which it is produced." The torsion of the suspending wire balances the displacing force. This multicellular electrostatic voltmeter is also made in another form for vertical use.

Fig. 74 illustrates this, and gives a very good perspective view of the instrument. The quadrants and vanes can be seen, also the dash-pot below, as well as the torsioned head above. The short-circuiting switch is at the side. The plumbob is a device for adjusting the instrument vertical, and, consequently, the vanes and quadrants will be level. The framework is attached to the wall with screws, and the milled head screw seen

in the figure at the bottom is one of two screws for placing the instrument perpendicular. Behind, there is another screw, which is not seen, for tilting the instruments backwards or forwards as may be required. It will be noticed that the aluminium pointer in this instance is bent to show on a vertical scale.

These voltmeters are exceedingly practical and convenient.

It may be mentioned that the metal case protects the instrument from draughts and from outside electric influences.

The multicellular voltmeters are made in a series of three or five instruments for indicating from 40 to 1,300 volts.

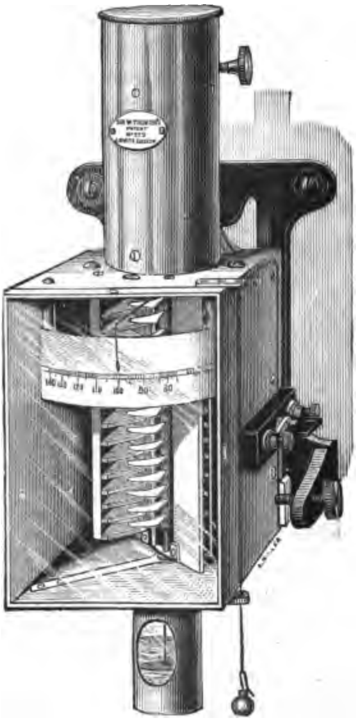


Fig. 74.—Multicellular Voltmeter, with Vertical Scale.

Aluminium being electropositive to brass, when the positive wire is attached to the insulated (or vane) terminal, the reading is about $\frac{1}{5}$ volt too low; with the opposite connections the reading is as much too high. With alternate currents the indications are correct.

There is also made an exceedingly accurate standard

voltmeter, which reads to within $\frac{1}{50}$ of a volt of the true value. The scale is read by means of a telescope, the scales (there are two) being observed in a small mirror on the voltmeter, in a manner similar to the same method as employed with reflecting galvanometers.

Lord Kelvin has introduced some forms of voltmeters on a similar principle to that employed in his balance meters, but they have been superseded by his electrostatic voltmeters. Fig. 75 represents his gold-leaf electroscope. It will be observed that the gold-leaf hangs against a plate of brass within the case, the brass plate acting as a repulsion plate. The gold-leaf is clamped at the upper end, so that when the leaf is repelled it becomes a pointer; and to eliminate parallax error the scale is repeated at the back of the case, as seen in the figure. The small metal frame, in a horizontal position, can be shut down to hold the leaf in place, when the instrument is to be moved from one locality to another. When this frame is open, it acts as a repelling plate to prevent the gold leaf touching the top of the case, should very high pressures be put upon the instrument. The case itself is made of brass, and the circular form given to it on one side is favourable for the action of the instrument. The front on

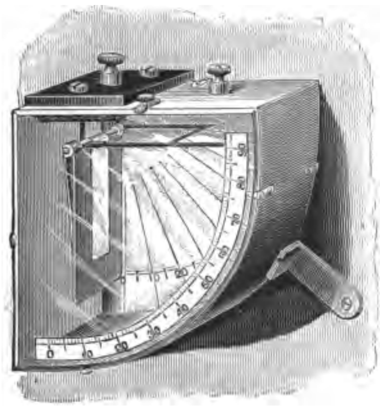


Fig. 75.—Gold-leaf Electroscope.

one side is of glass, and can be opened. The brass framework which carries the gold leaf is attached to a piece of ebonite at the top of the case. This electroscope can be used for measuring E.M.F. up to about 5,000 volts, but it must be calibrated by means of a standard instrument; it may also be employed in the place of the ordinary gold-leaf electroscope. The gold leaf employed should be very thick. The author has one of these instruments made with glass on both sides for use with the optical lantern, for which purpose it is admirably suited.

Fig. 76 shows a standard vertical electrostatic voltmeter. It will be observed that there are two sets of fixed quadrants. The back ones can just be seen at the edge. The swinging vane carries a pointer, and on the back of the case, which is made of metal, two stops limit the action of the vane. At the lower end of the vane there is an arrangement to attach weights, for altering the value of the divisions on the scale; these weights are added successively: there is also a little weight for adjusting the stability. At the top, outside the case, will be observed a handle. This moves a slight rod inside the case, which hangs by silk threads and is intended to be used as a checker. In the bottom of the case the small box of weights is seen. The glass front slides out, and to improve the working of the instrument a strip of tinfoil is put on the glass, and it reaches up a little beyond the axis of the vanes. This is not shown in the figure. The vanes are supported on knife édges, and a convenient way of rendering the instrument portable is by screwing the vane to the left-hand stop, which at the same time relieves the knife edges.

The actual working instructions are sent out with all

Lord Kelvin's instruments, so that details in this direction need not now be dwelt upon. These voltmeters are made to indicate from 200 to 20,000 volts. But this range cannot be contained in any one instrument.

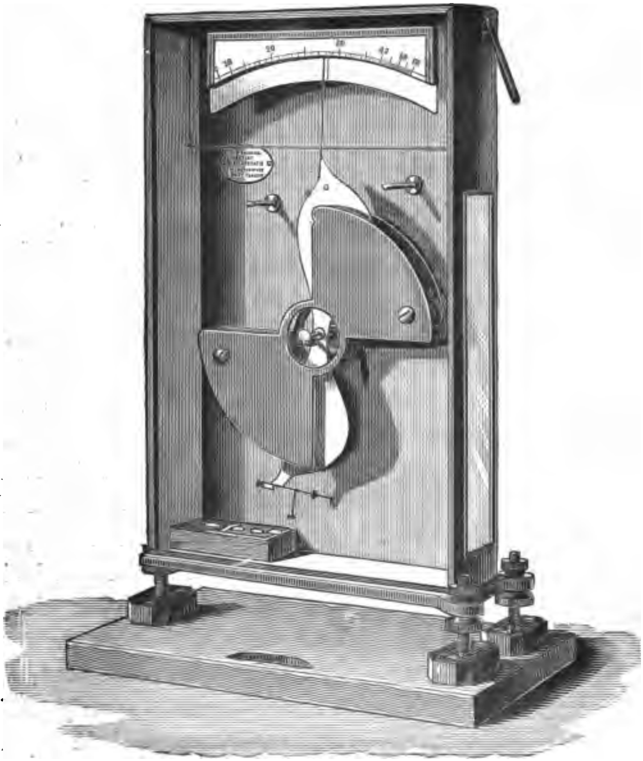


Fig. 76.—Vertical Electrostatic Voltmeter.

No. 1 reads from 200 to 4,000; No. 2, from 400 to 8,000; No. 3, from 800 to 12,000; and No. 4, from 1,000 to 20,000.

The readings are in volts direct, and the scale is graduated in each case from 0 to 60.

For higher pressures the electrostatic balance is employed. There are two existing forms of this instrument: one reading 2,000 to 50,000 volts, and the other 5,000 to 100,000 volts. It is quite evident that, where such high pressures have to be measured, sparking distance becomes an important consideration; and all parts

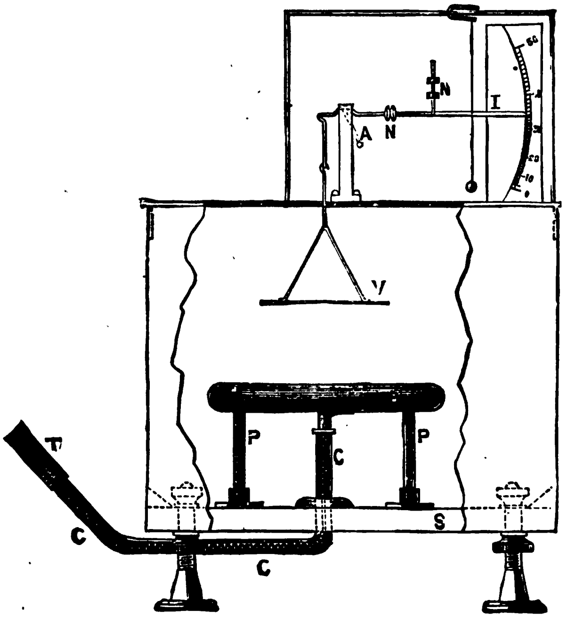


Fig. 77.—Electrostatic Balance.

of the apparatus, between which difference of potential exists, must be placed far apart. These balances, therefore, are of very large size, and are nicknamed "Gasometers." The two balances mentioned are similar in construction, so that a description of one is applicable to both. A diagram of this balance is shown in Fig. 77.

S represents the base, or platform, which is carried by three levelling screws. Over this goes a large metal cylinder closed at the top by a flat metal cover, which has in it a hole to permit the working parts to pass through. Upon the cover is fixed a metal case, which contains the scale and other parts, with a glass front. C C is a cable within a glass tube, and T a terminal protected with an ebonite tube. This part, where the connection is made, has recently been modified in a more convenient form. This cable or other attachment is brought in contact, by means of a spring, with a nickelled metal circular table B. The table is supported upon three glass pillars, P P, by the "hole, slot and plane" method, so well known; therefore, the table may always be replaced in the same position. V is a light scale pan, which is suspended from the lever portion, shown above, the knife-edge pivot being carried by the pillar at the top of the case. I is the indicating needle; N N, weights for adjusting the instrument; and A, a stirrup upon which to hang various weights for altering the value of the scale divisions. There will also be observed the checker near the letter I, consisting of a thread with a little weight at the lower end. The handle for moving this thread comes through the top of the case. Since the diagram was made, the checker has been somewhat improved. Naturally great care must be taken when using these instruments, since the pressures requiring measurement are exceedingly dangerous. The scales are marked 1 to 50, and the weights are put on only one at a time. Readings are direct in volts.

It is always desirable, in using instruments for measuring high E.M.F., to place outside each instrument two points, one connected with each lead, or when

only one is employed, then the second lead and point should be connected to earth as well as the case of the instrument; and these points (or dischargers) should be so adjusted that their distance is rather less than any sparking distance in the instrument employed. Thus, if too high a pressure is put on the voltmeter, the spark will jump between the points and not injure the apparatus.

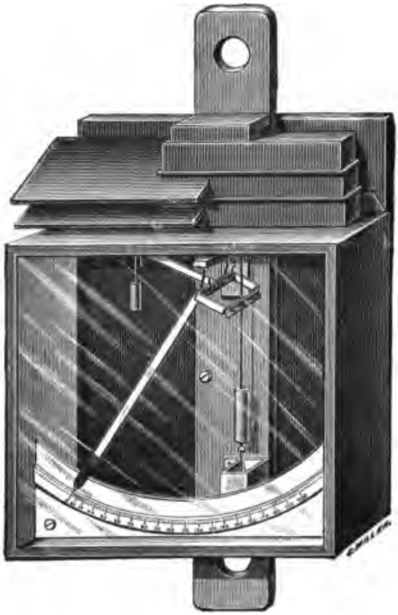


Fig. 78.— Kelvin Ampere Gauge.

Fig. 78 is an illustration of the Kelvin ampere-gauge, which may be used for any type of current; and to all intents and purposes it is a standard instrument, when once adjusted by a standard instrument proper. On the top of the case will be noticed a special form of coil consisting of copper plates insulated with mica, and an intense field is created, which draws up into its axis a thin core of soft iron wire when the current is passing. This core is pulled up against gravity. The little balance weight can be seen at the upper part and on the left-hand side within the glass case. It will be observed that the iron core is produced perpendicularly, so as to carry a weight which keeps it

upright, and from being attracted to the side of the solenoid; and below the weight hangs a disc, which is in the oil contained within the little metal rectangular cup to render the instrument dead beat. The suspension method is equivalent to the knife-edge method. The cable is soldered to the portions projecting above and below the instrument, and which are also used for fixing it to the wall. The readings are direct.

The Kelvin standard instruments, suitable for measuring alternate and direct currents, may now be described. These have taken so important a place in modern electricity that plates of the whole series are shown, although it will not be necessary to give a minute account of them all. Fig. 79 is a view of the standard centi-ampere balance, which measures from 1 to 100 centi-amperes. In this particular instrument the movable portion may be relieved from its suspension by turning the little knob in the front of the base. This exists also in the deci-ampere balance, which reads from 1 to 100 deci-amperes. In all the other instruments the suspended portions cannot be relieved, since Lord Kelvin considers that it is an advantage to keep the movable portions always suspended, except during transit. In those instruments where relieving-gear does not exist, suitable arrangements are made for rendering the instrument portable.

Fig. 80 represents a standard deka-ampere balance, which reads from 1 to 100 amperes.

The hecto-ampere balance indicates from 6 to 600 amperes.

The kilo-ampere balance is for use with currents from 25 to 2,500 amperes. It is shown in Fig. 81.

The standard 1 ampere balance, such as is used by

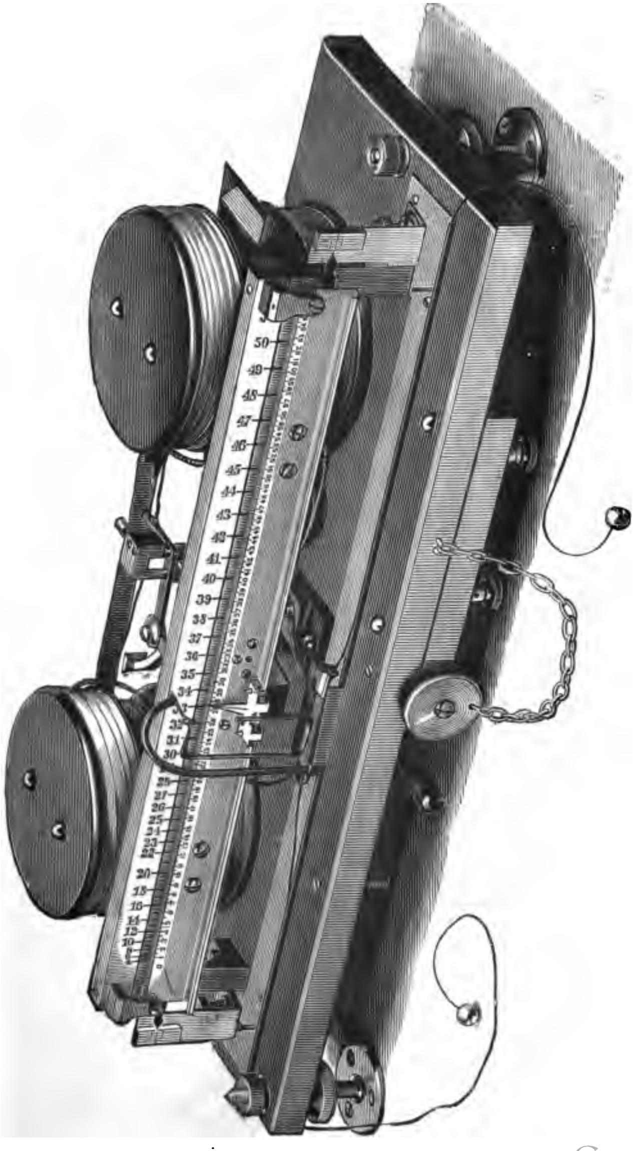


Fig. 79.—Standard Centi-ampere Balance.

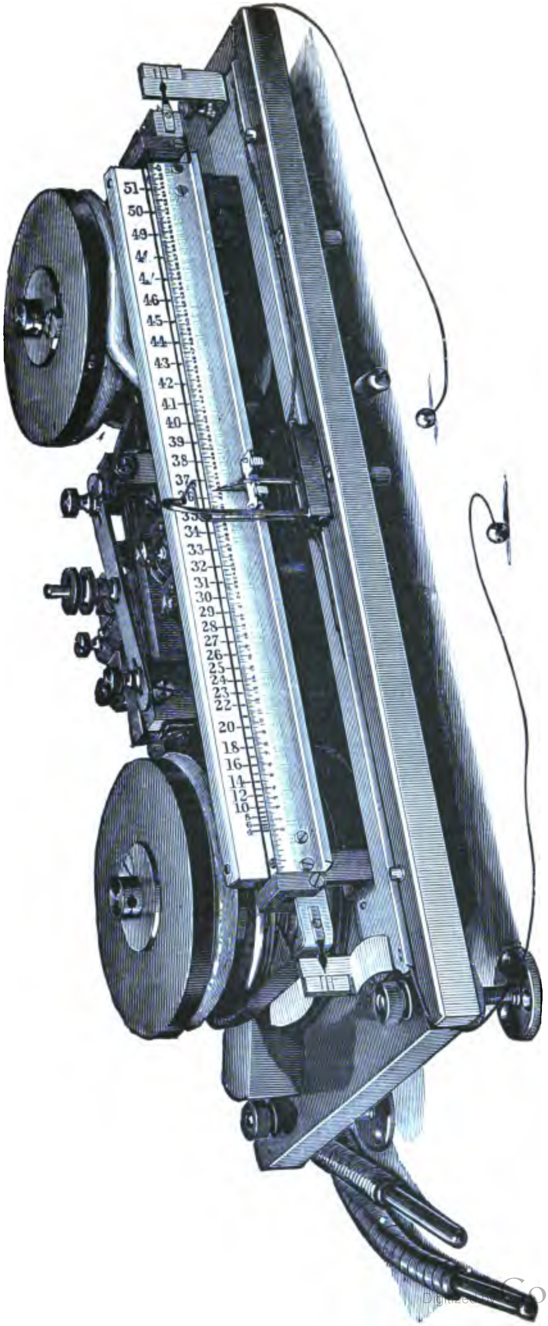


Fig. 80.—Standard Deka-ampere Balance.

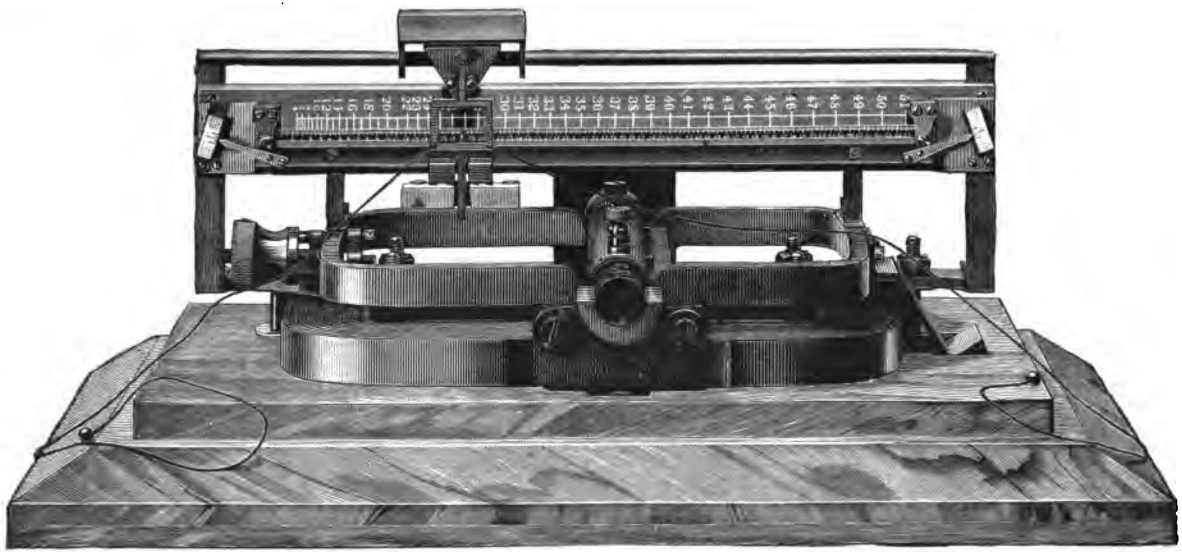


Fig. 81.—Standard Kilo-ampere Balance.

the Board of Trade for standardising purposes, is illustrated by Fig. 82.

This instrument is exceedingly accurate and is intended to measure only one ampere, although it can be made to indicate otherwise, if so desired. The accuracy is within $\frac{1}{8}$th per cent.

Generally speaking, the Kelvin instruments are made to read from 1 to 100 times, the smallest current for which its sensibility suffices. These balances may carry 75 per cent. of the maximum current continuously,

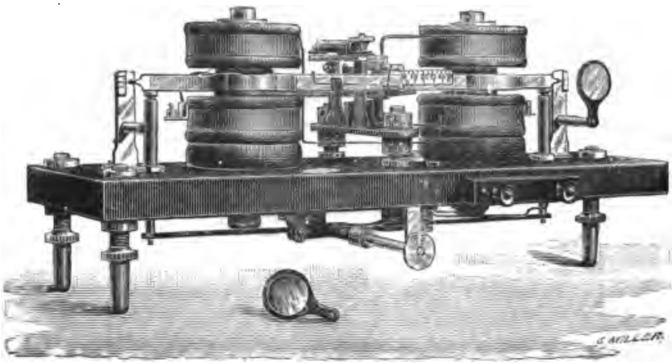


Fig. 82.—Standard 1 Ampere Balance.

and carry their maximum current for all periods required for standardising purposes.

All these instruments depend upon the properties possessed by the electric current, and which were discovered by Ampère, between movable and fixed portions of an electric circuit.

A brief description of any one of the balances will cover them all, and where any special modification exists it will be mentioned afterwards. The balance consists of two fixed rings at each end of the base, and

between each pair is placed a movable ring, these movable rings being rigidly attached to the ends of a bar. This movable portion is suspended, balance fashion, from a fixed point, by a number of very fine wires, which are so placed as to give the appearance of two very short and broad pendulum springs, placed side by side. Lord Kelvin finds that such a mode of suspension has less friction than other methods. This suspension, being divided, permits the current to enter the movable portion through the one part and leave it through the other. The current traverses the whole of these rings successively, which may consist of one or more turns of wire.

Consider the action of a pair of fixed rings upon the movable one between them at one end of the instrument. The direction of the current within these rings is so arranged that the movable ring is attracted by one fixed ring and repelled by the other. The effect produced by the rings at the other end of the balance is similar, and the direction of the current in them is so arranged as to increase the effect produced on the other side. Consequently, when a current is passing, the movable rings become displaced from the horizontal position in which they were approximately in the first instance.

At the extremities of the balanced portion there are bars, each of which bears a pointer; and these indicate upon two scales, one fixed at each end of the slate base. The bars also support an aluminium scale, which has a set of divisions engraved upon it, and also a platform with a slider. There is also a fixed scale called the "inspectional scale," with large figures upon it, as may be seen in the figures. The slider carries different weights, and the divisions upon the scale have values

which vary according to the weight placed upon the slider. The slider has a finger which points to the divisions upon the movable and fixed scales at the same time: the lower divisions, upon the movable scale, are employed for accurate readings; and the upper ones, upon the fixed scale, give approximate values in amperes direct. The upper scale is termed by Lord Kelvin the "inspectional scale," and for all ordinary purposes the readings obtained upon it are sufficiently accurate. The true values are ascertained by doubling the square root of the reading upon the lower scale, which is engraved on the aluminium bar. This scale has notches, to show the true positions, corresponding to the numbers upon the inspectional scale. In order to obtain a reading when a current is passing through the instrument, it is necessary to pull the slider along the scale until the movable rings take up the horizontal position; which is indicated by the little pointers, on the suspended portion, upon the scales attached to the ends of the base. Thus the weight, so to speak, balances the current. The right-hand end of the movable portion carries a small pan, into which is put a suitable weight to counterpoise the one that may be placed upon the slider when at zero. The slipping of the weight into its proper position is effected by an ingenious self-releasing pendant, which hangs from a hook attached to a sliding platform. The latter can be pulled in either direction by means of a silk cord. The instrument has adjustments for obtaining the true zero point, and also is supplied with levelling screws. The useful range of each instrument is from 1 to 100 times of the smallest current for which it was intended. The instruments are sent out with four pairs of weights; one pair is used

for each setting, one for the sliding weight, and one for the counterpoise. For instance, in the deka-ampere balance, for the first pair make the readings, per division, upon the inspectional scale, 0·25; second pair, 0·5; third, 1·0; fourth, 2·0. The values are multiples of an ampere. Each instrument has a glass cover, not shown in the diagrams, and this carries a movable magnifying-glass for reading the divisions.

With all these instruments not only are complete instructions issued under Lord Kelvin's own supervision, but also certificates of accuracy.

The centi-ampere balance, when used with an additional anti-inductive resistance and a thermometer for taking the temperature of the coils, may be employed as a standard voltmeter.

The measurement of very heavy currents can better be accomplished by the use of wattmeters, because in these the stationary coils are large; whereas the movable ones, being placed in shunt, are small and light. Clearly, when the watts are known, by ascertaining the E.M.F. the amperes flowing can be found, also the inverse.

Such instruments are now shown. Fig. 83 represents a composite balance, which may be employed, at pleasure, as a hecto-ampere meter, voltmeter, or wattmeter. Stationary thick coils are seen at one end of the balance, and similar fine-wire coils at the other.

Fig. 84 illustrates the standard kilo-watt balance, for very heavy currents of the direct type.

Fig. 85 is an alternate current kilo-watt balance.

The direct current balance can be used for currents from 0·1 to 10,000 amperes, and the alternate current instrument up to 3,000 amperes. The difference between the alternate current apparatus and the other one is that

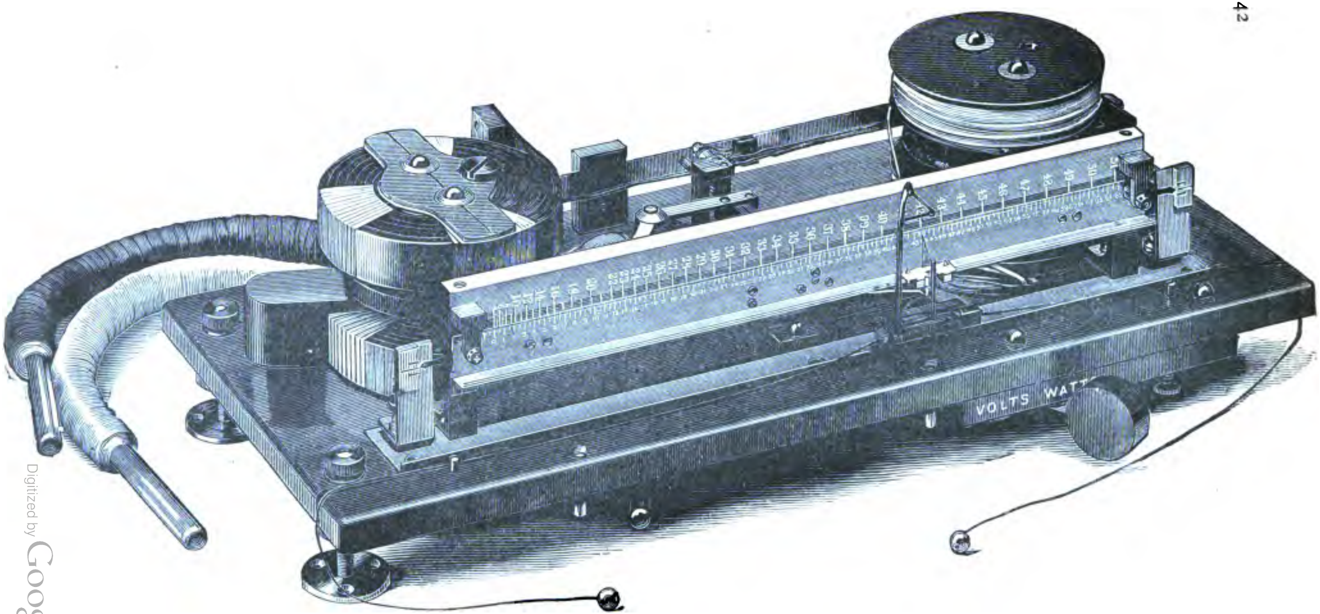


Fig. 83.—Composite Balance.

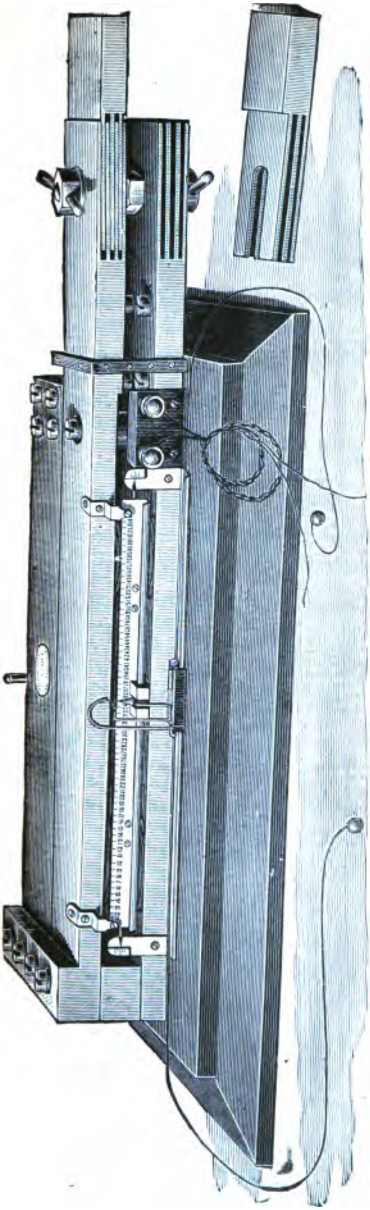


Fig. 84.—Standard Kilo-watt Balance.

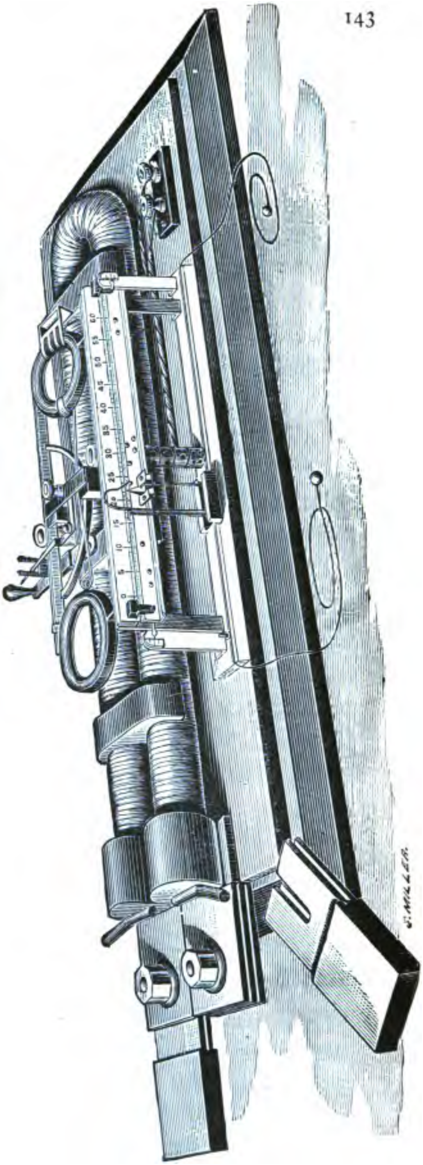


Fig. 85.—Alternate Current Kilo-watt Balance.

in the former the stationary coil is built up of strand wire in a particular way, to avoid errors due to the inductive effect of one arm of the coil upon the other.

The core is hollow. The strands inside one leg are brought to the outside on the other, besides being wound in the reverse direction, to eliminate the inductive effects of one leg of the U upon the other leg; and very equal distribution of the current in the conductors results. Tubes of brass are inserted within the coil to keep this in shape. Air can be blown through the tube to cool the coil if so required.

With watt-balances it is usual to employ a resistance in series with the fine-wire coils. These resistance coils have a large ohmic value compared with the fine-wire coils upon the instrument, and are wound anti-inductively; which is effected by returning the winding upon itself. This is equivalent to winding two wires upon a reel at once, the ends of the wires at one extremity of the reel being used for the connections and the other ends joined together. The accuracy of these watt-balances is mainly due to the equal distribution of the current in the main coils, and the large value of the anti-inductive resistance coils compared with the fine-wire coils.

An engine-house wattmeter, with the cover off, is shown in Fig. 86. It indicates to within 1 per cent. of accuracy. The main current is passed through two copper rectangles, inside each of which swings the fine-wire coil placed in shunt. This swinging portion carries the pointer to indicate on the scale. The current is brought to the movable portion by spiral palladium springs, which also assist to give stability to the instrument. The base is made of slate. The movable coils

are attached to an aluminium frame, suspended, as separately shown in Fig. 87. It will be noticed that one coil carries the pointer and the other a little weight for adjustment purposes. The suspension is by means of two hooks, and of such a nature that the coils cannot be displaced. The method of suspension is a very favourite one with Lord Kelvin.

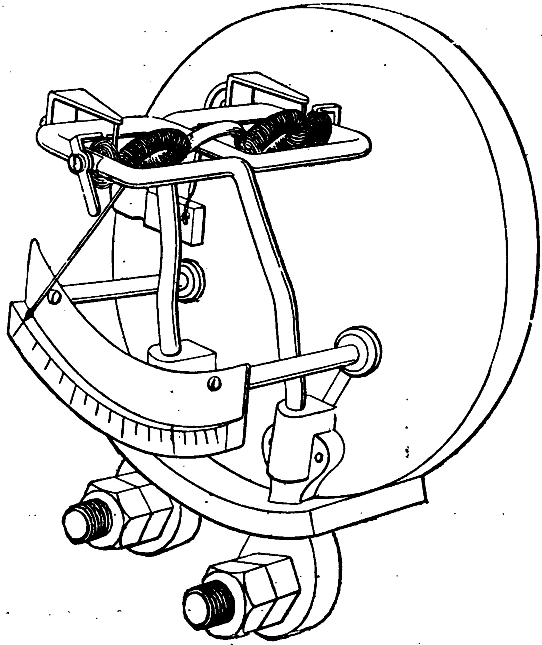


Fig. 86.—Engine-house Wattmeter with Case removed.

For registration, instruments very similar to the registering aneroid barometer are used—*i.e.* a needle marks a line upon a cylinder rotated by means of clockwork. Messrs. Richard, of Paris, have taken up the manufacture of this class of instrument as a speciality, and

they have London agents. The working parts consist of some form of ammeter, or voltmeter, with a long needle which carries at its end a pen, or some other marking-point, which traces a line upon a piece of paper stretched round a rotating drum. In most instances the electric apparatus is some ordinary form of ammeter or voltmeter. In some cases a hot wire, or carbon, is employed for the meter portion; in others the needle is a weightless one—*i.e.* a ray of light reflected from a galvanometer mirror, the paper in the latter instance

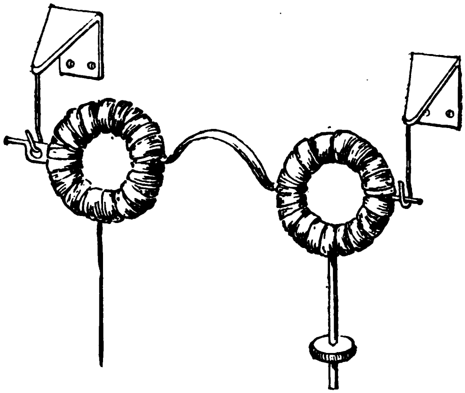


Fig. 87.—View of Fine-wire Shunt Coils, showing Details of Suspension; controlling Springs removed.

being photographic sensitive paper. The writer believes that he was the first to use this method of registration, as applied to electric-light installation work many years ago.

Several other forms have been brought out, including those of Major Holden.

Fig. 88 represents Richard's voltmeter.

Fig. 89 illustrates Holden's recording voltmeter.

Fig. 90 is the recording ammeter, worked by a hot-strip method.

The principle of Holden's photographic pressure recorder may be gathered from the outline diagram, Fig. 91. It will be observed that a galvanometer stands at

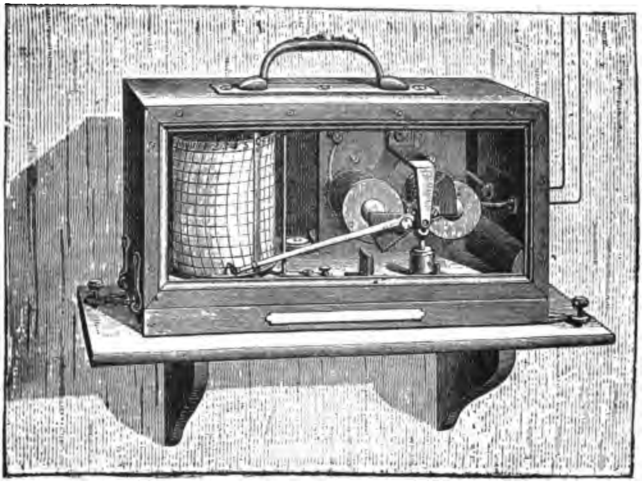


Fig. 88.—Richard's Voltmeter.

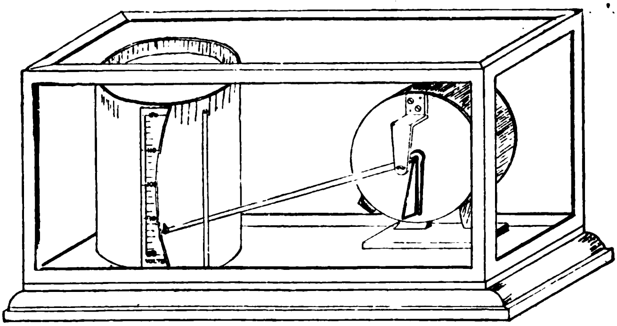


Fig. 89.--Holden's Recording Voltmeter.

one end of a closed case, and at the other the rotating cylinder around which is wrapped the sensitive paper. Major Holden's instruments are supplied by Messrs.

Drake & Gorham. The hot wire apparatus, and strip instrument of Major Holden may be used with any type of current. In most cases registering apparatus are improved by the addition of oil or glycerine dash-pots.

In some instruments the marking-needle does not

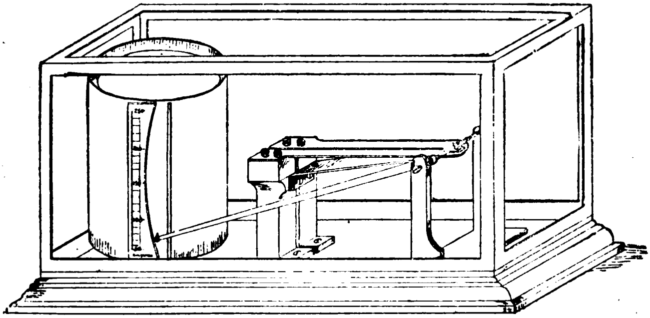


Fig. 90.—Holden's Recording Ammeter.

press upon the paper continually. The line consists of a series of dots placed close together, the object of this method being to reduce the friction upon the paper to a minimum.

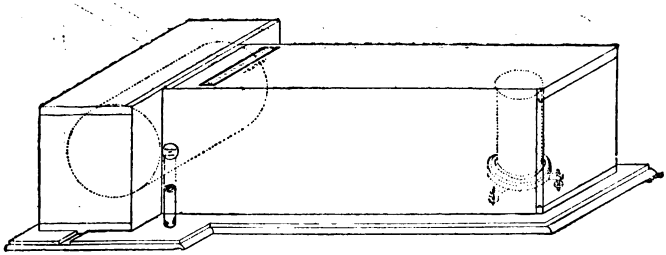


Fig. 91.—Holden's Photographic Recorder.

Another piece of apparatus, which occupies an important position at the present day, when so many houses are supplied by a public company, is the electricity meter for measuring the quantity of energy taken by a

householder over a given time. These meters for electricity occupy the same position as the gas meter does in regard to gas. So many forms of this apparatus have appeared from time to time, that a description of all of them would be tedious, and little would be gained by giving such an account. The truth is that there is probably no perfect meter at this moment; a perfect meter would be one which would register, from the smallest current likely to be passing into a house to the largest for which the meter was made, with accuracy throughout. The majority of meters do not register at all for a very small current passing, and, on the other hand, some that do take account of these small currents are not necessarily correct at the higher ranges. Those instruments which take no account of small currents are clearly unfair to the supply company, since the householder might have one lamp on all day, and the apparatus take no account of it. On the other hand, some meters register in the opposite way for large currents. However, it may be said that, in almost every case, the electricity meter is more favourable to the consumer than to the supply company. The principles employed in these instruments are so numerous that a work might be written on this subject alone. It will be sufficient here to describe but two or three types.

Ferranti's meter (one type is shown in Fig. 92) depends for its principle on the rotation of mercury by the current, under suitably arranged conditions. The current passes into the mercury at the centre of the bottom of a cylindrical cup and passes through the mercury to the periphery, the bottom of the cup being made of a non-conductor. The mercury in consequence rotates, and the rotation is proportional to the current. Floating on the

mercury is a little fan, which rotates with the mercury. This fan carries a spindle, which runs a train of wheels, some of them carrying pointers that mark upon dials very similar to those seen on gas meters.

Since the pressure is supposed to be constant on the mains, the pointers indicate upon the dials the energy (in Board of Trade units) which the householder has used. In most meters the Board of Trade units are read direct upon the dial, but in some instances the readings have to be multiplied by a constant. In the Ferranti meter the magnetic circuit is a closed one, so that the readings are not disturbed by currents and masses of iron in its proximity. Ferranti's meters are also made as energy meters, and for alternate as well as direct currents.

Fig. 92.—Ferranti's Electricity Meter. Horizontal Dials.

It is quite clear that, unless the pressure on the mains is kept fairly constant, the result will be unfair to the consumer, if it should fall below normal, as well as if it rises above; for in the latter case, although the supply company may be the loser, the lamps of the customer are being injured.

Professor Forbes and others adopt as their principle the heating properties of the current. In some apparatus,

such as Dr. Hopkinson's, the meter practically consists of a small electro-motor. A large number of meters

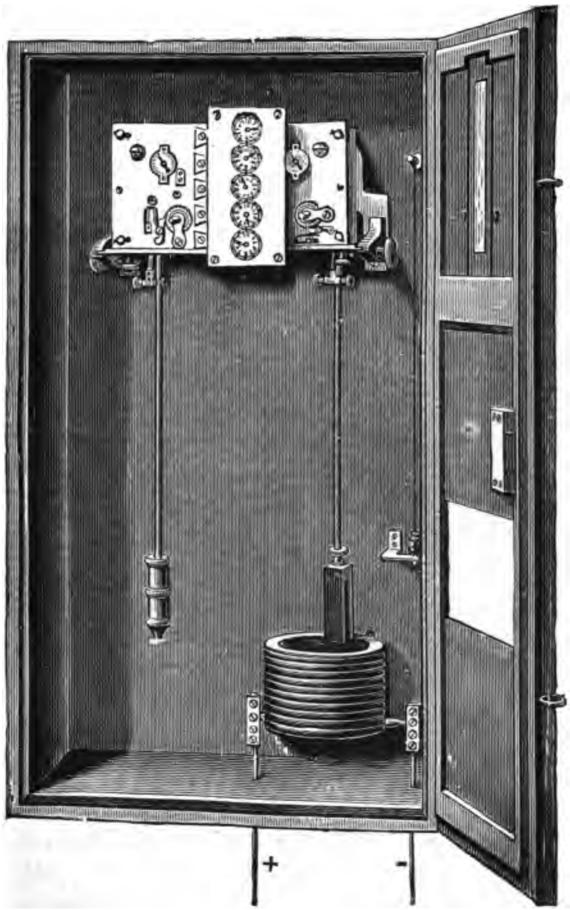


Fig. 93.—Dr. Aron's Meter.

are made to vary the registrations by means of a "snail." The snail lifts a lever, or some other piece of apparatus, to a greater or less height according

to the position of the snail; and the position of the snail is given by some form of electrical apparatus.

Favourite meters at this time are those depending on the pendulum principle. The principle of pendulum meters is as follows: One pendulum swings uninterruptedly at its own period, and the rate of vibration of a second pendulum is disturbed by the current passing

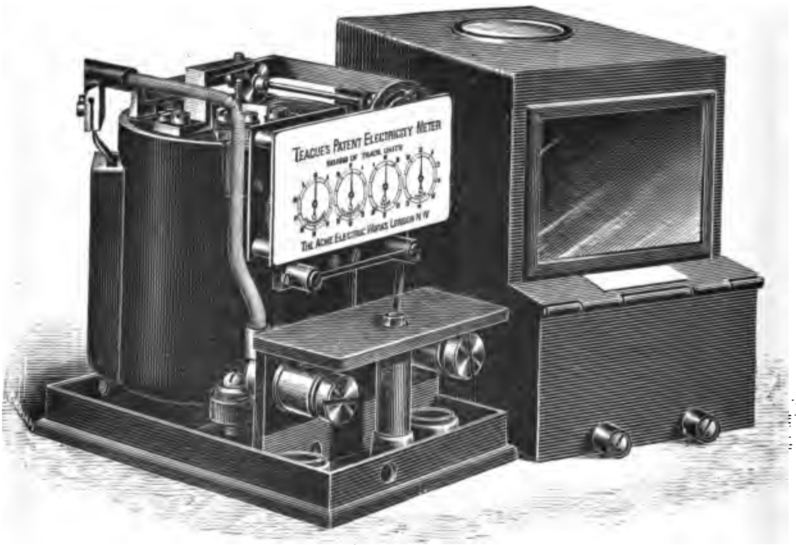


Fig. 94.—Teague's Meter.

through the instrument, special arrangements existing to effect this, the disturbance having a definite relation to the quantity of current passing, or energy, if constructed to register this, at any moment. The movements of the two pendulums are integrated upon a dial or dials.

Professors Ayrton and Perry were the first to devise

meters in such a form. Meters on this principle, chiefly in use at the present time, are those of Dr. Aron. Fig. 93 shows this meter. The left-hand pendulum is free, and the right-hand one is influenced by the current passing through the coil below the iron bob.

In one form of instrument the measurements are made by the evaporation of ether.

Edison's meter is a thing of the past. It is a chemical meter, depending upon the deposit of some metal. This instrument requires a shunt resistance, and therefore is wasteful for large currents.

Another well-known meter is that of Mr. Teague. Its appearance is shown in Fig. 94, with the cover off. It is made at the Acme Electric Works.

Fig. 95.—Westinghouse Co.'s Meter.

The meter made by the Westinghouse Company is also largely in use, and it is seen in Fig. 95. This meter was designed by Shallenberger.

A new one has been introduced by the General Electric Co. and is spoken of in very glowing terms, but sufficient time has not elapsed to allow a fair trial of the

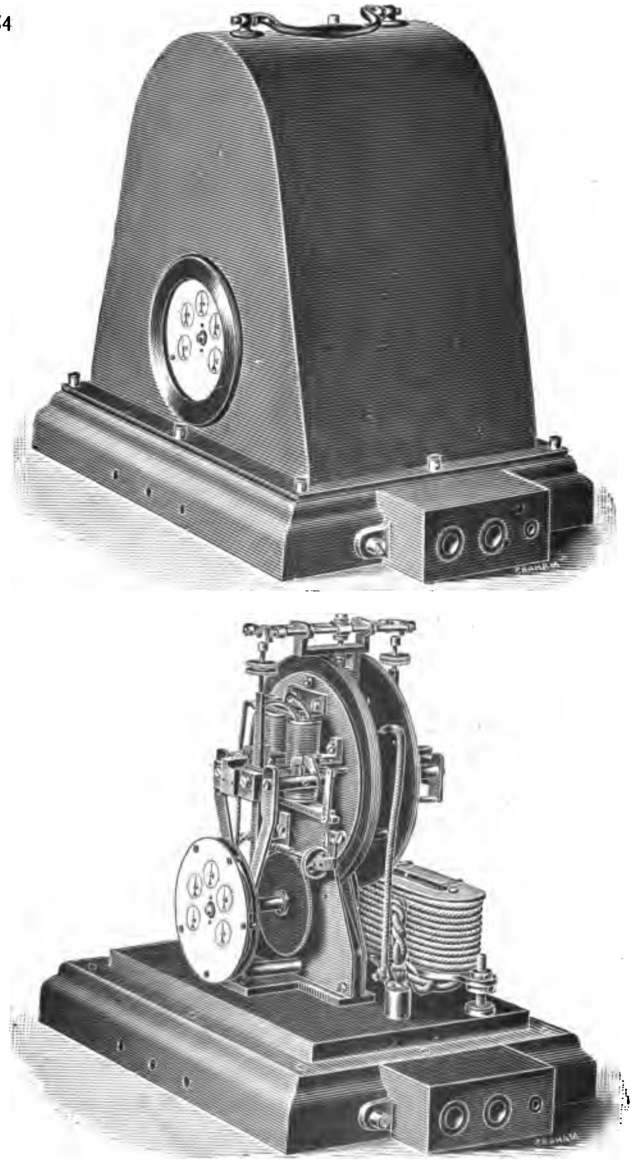


Fig. 96.—General Electric Co.'s Meter (Cover on and off).

instrument. The inventors are Mr. Binswanger and

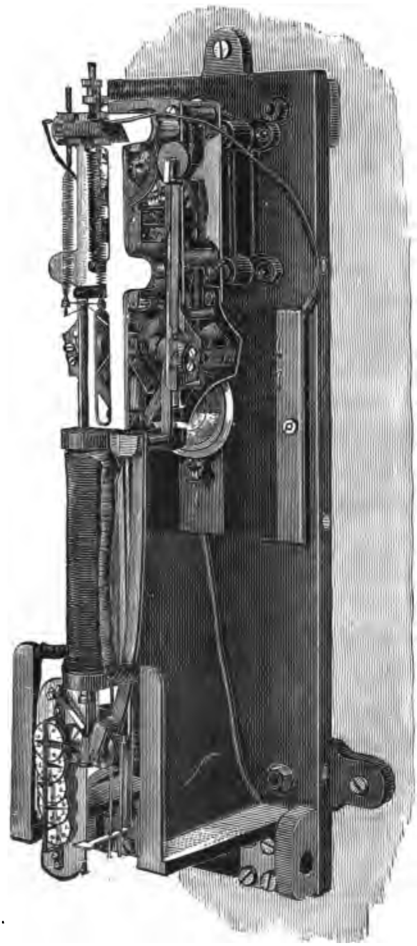


Fig. 97. — Kelvin Electricity Supply Meter.

the late Mr. Reckenzaun. This meter is shown, with the cover on and off, in Fig. 96.

Fig. 97 represents Lord Kelvin's latest form of elec-

tricity meter, with the cover off. The instrument consists of four parts, all attached to a slate back. They are as follows, commencing with the upper part of the plate: a clockwork actuated by a little motor placed below it; then a solenoid which carries the main current, the core within it being an electro-magnet with a very high resistance and placed in shunt; and below the solenoid the indicating apparatus. The principle upon which the meter acts depends on the length of core drawn into the solenoid. This core projects just below the solenoid, when no current is passing; and, consequently, by ascertaining the length of core projecting from the solenoid at any time, the amount of current flowing can be measured. This is effected by a platform rising and falling continually, causing a wheel to travel over the projecting part of the core, and in such a way that the wheel moves in only one direction. In this manner the length of core projecting beyond the solenoid is measured and registered upon the dials.

The principle of making the core of a solenoid an electro-magnet is new. Lord Kelvin has shown that if the core is made of soft iron and of small size, then the inaccuracies inherent in measuring instruments depending upon the solenoid method can be obviated by magnetic saturation of the core. A very small shunt current is used for this purpose. The core is surrounded with a fine wire coil of high resistance. In the ammeter depending upon this principle, a key is depressed to permit the current to pass around the core. This ammeter is termed the "tubular ampere gauge," and is very compact.

CHAPTER IV.

GOVERNORS.

IN a well-designed electric-light installation governors of some kind are necessary, in large ones they are indispensable. By "governor" it is not to be understood the ordinary governor found on a steam-engine, gas-engine, and other types of prime motors which are here referred to; for these exist for the safety of the engine rather than for the well-being of the installation. The purposes of governors required in an electric-light installation may be comprised under two heads: (1) to maintain a regular pressure, and (2) to sustain a constant current. The first type may be employed for keeping the E.M.F. of the current constant when charging the cells, or for keeping the pressure constant on the lamp lines. The constant-current governor may serve for maintaining the charging current of an accumulator constant, or for keeping constant the current flowing in an arc-light or series circuit. Again, these governors may be modified for increasing, or for decreasing, the E.M.F. at some definite rate for certain rise or fall of current; and the same may be said in respect of the current when the pressure varies. The most simple way of working such a governor is to make the electric energy itself work it. Some applications of this apparatus will be described when various methods

of practical working are dealt with. When a governor is constructed for regulating pressure, the electrical portion usually consists of a high-resistance coil placed in shunt. On the other hand, when the apparatus is to regulate current, the coil is so placed that the main current passes through it. The E.M.F. can be maintained constant (or made variable according to some law, if so desired) upon a lamp circuit in many ways: (1) by putting resistances in and out of the field-magnet coils, which in the case of a shunt-wound dynamo is very easy; (2) by placing in one of the lines a few cells similar to the usual storage cell, or any other form of voltameter, in such a way that the E.M.F. is decreased on the lamp circuit for every cell that is placed into that circuit, the governor putting in and taking out these cells automatically; (3) by putting resistances into one of the leads of the outside circuit—an undesirable method, since the resistance must be altered for every variation in the current flowing, which is not the case when counter E.M.F. cells are used, provided that these cells are large enough to carry the maximum current with ease.

There are other methods of regulation which will be referred to in the next volume.

Electric governors may be placed upon the gas-engine or steam-engine, in order to cut off the steam or gas, that its power may bear some definite relation to the electric energy produced.

An electric governor on the steam- or gas-engine is of little use for obtaining a very steady light, on account of the great momentum of its moving parts. All governors are best placed in connection with the dynamo and leads. Where an accumulator is used, a governor on

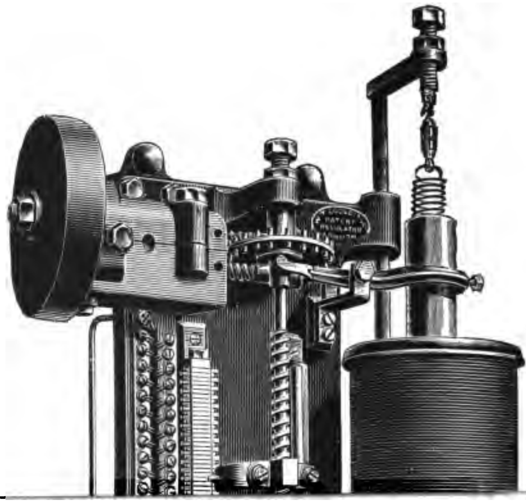


Fig. 98. — Goolden Automatic Regulator and Resistance.

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the engine is of little value for constant E.M.F. as well as for constant current. It also costs more to put a governor on the engine than elsewhere, and its position there renders it more liable to injury. There is a phenomenon somewhat resembling momentum in the case of magnetism, but it can be reduced to such an extent as to be of no consequence.

A governor placed to regulate the E.M.F., or current, of the dynamo may work fast or slow. It may "hunt," that is, fail to reply at once to the call made upon it, and this hunting, in practice, shows itself by passing and repassing the proper step on which the switch finger should remain; but this is of no importance, for steadiness is soon established. The "hunting" is caused by the time required for the iron in the magnets to respond to the altered shunt current. Hunting, in the case of an engine governor, is a serious matter, for then the engine alters its speed by fits and starts.

Two types of governors will now be described. Many others exist, but none of them are more satisfactory than those to which attention will be drawn; since the author has had them at work many years without any hitch occurring. One is suitable for putting resistances in and out of the field-magnet coils of a shunt dynamo, and the other also for this purpose or for putting counter E.M.F. cells in and out of the main circuit.

The Goolden governor (shown in Fig. 98) consists of three parts. One is a solenoid, containing a core suspended by a spring. When the governor is made for constant current, the main current is passed through the coil, which has a low resistance, and the core is drawn down into the solenoid against the spring, when the current is large enough to overpower it, the spring

drawing it up again when the current falls below this point. When the apparatus is used for constant E.M.F., the coil has a high resistance and is placed between the leads, the action being the same as that explained, when the solenoid is used for the main current; since a higher E.M.F. sends more current through the coil, and *vice versâ*.

The second part of the governor consists of a switch with many steps arranged in a straight line, connected with resistances, which are placed in the shunt circuit of the dynamo field-magnets. The finger of the switch is caused to move in one direction or the other, putting resistance in or out of the shunt, according as the core is drawn into the solenoid by the current or pulled out of it by its spring; which depends upon the current in the coil exceeding or falling below a given amount.

The third portion of this governor is the apparatus necessary to control the movements of the switch, according to the position of the core. It consists of a lever attached to the core, and is worked up and down by it in such a way as to raise or to permit to fall a wheel carrying pins around its periphery, like a double crown wheel, through which a vertical shaft passes. This crown wheel is so keyed upon the shaft that, although free to slip down upon it, yet, when the wheel is rotated, the shaft must turn with it. The shaft has upon it a screw which works the finger of the straight line switch up or down, according to the direction in which this arbor is turned. On each side of the crown wheel mentioned, there are two screws (turning in opposite directions) rotated by the engine. The elevation is shown in detail in Fig. 99, and in plan in Fig. 100.

The details of this portion of the governor are lettered.

The same letters in the two figures indicate similar parts. G is the pulley; F and F′ are the spindles; H and H′ the screw driving gear; D and D′ the plain part of the spindles; E and E′ the engaging screws for driving the wheel which works the switch; K the centre point of switch spindle; B a wheel, which carries pins, b, b, projecting above and below its surface around the periphery. These latter engage in the screw gear on the one side or the other, according to the position of

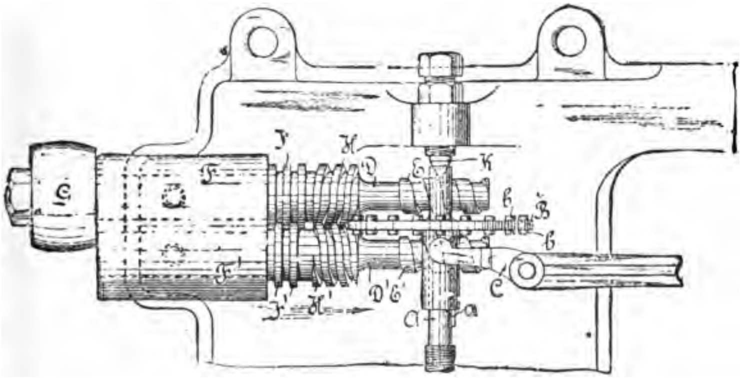


Fig. 99.—Positive Driving Mechanism. Goolden's Governor (Front View).

the lever C, which is attached to the core in the solenoid not shown in the diagram. The wheel B rises and falls upon the spindle A, but cannot turn without revolving this spindle, because of the presence of a key, *a*, which is so fitted as to allow of the rise and fall. The object of the arrangement at F is to retain the two spindles in their respective positions, for otherwise the various screw actions must tend to produce a shifting. The action is as follows. If Fig. 98 be referred to, the current which is to regulate, whether the shunt or the main current,

enters and leaves the solenoid by the wires A B. When this current becomes too great the core is drawn down. The lever to which it is attached consequently raises the crown wheel, which engages in the upper screw that is continually turning, because a belt from the engine rotates the pulley in connection with these screws. The crown wheel turning the shaft, which has the screw upon it, shifts the position of the switch finger so as to put more resistance into the dynamo-shunt circuit. The resistance frame is seen below the governor. The wire

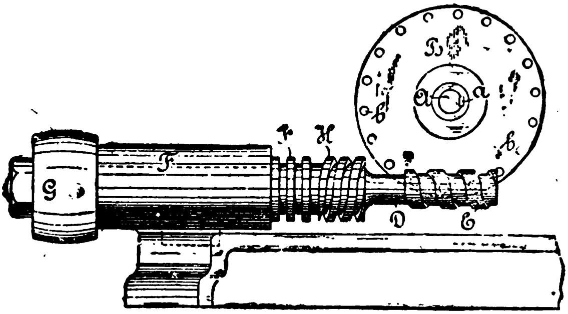


Fig. 100.—Positive Driving Mechanism. Goolden's Governor (Top View).

C and the wire to be attached at D go to form a loop in the dynamo-shunt circuit. When the current becomes too small in the solenoid, the spring draws the core out of the solenoid, the lever falls, and permits the crown wheel by gravity to fall upon the lower rotating screw, when the wheel will cause the shaft to revolve in the opposite direction. The switch finger will be moved along the switch in an opposite direction, taking resistance out of the shunt circuit. Thus it will be evident that the governor regulates with precision. The use of

this governor need not necessarily be confined to the special case described, but it may be inserted in any part of an installation, where governing is desired.

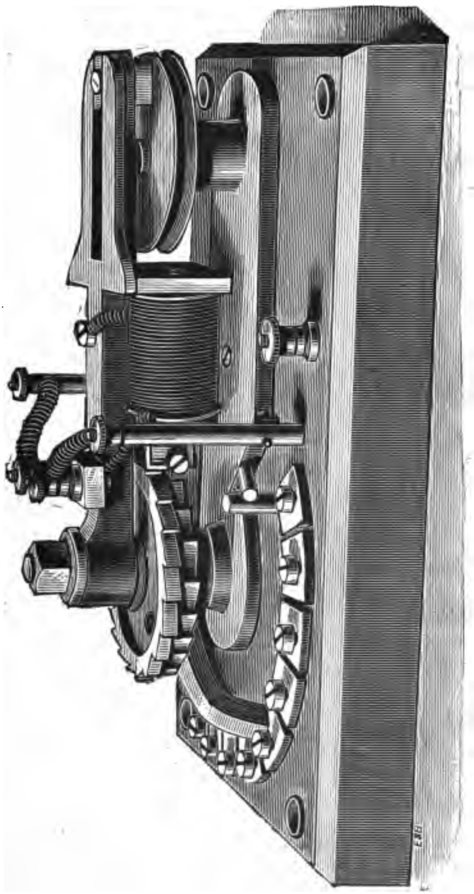


Fig. 101.—Salomons' Governor.

The next governor to be described is one devised by the author. The mechanical motion is similar to that

employed in the Porte-Manville governor. Mr. Denny Lane, of Cork, used the identical motion many years before the appearance of the Porte-Manville governor. His governor was devised for use on engines employed with gas-exhausters, and it was called by him the "brake and tappet" regulator, or duplex governor. This electric governor is made by Messrs. Woodhouse & Rawson; it is much simpler, and consequently more inexpensive, than Messrs. Goolden's. It is shown in Fig. 101. Its action is as follows: Two magnets are carried on a rocking frame, the motion being imparted by a pulley, which bears a pin, and which is rotated by the engine or some other moving portion of the installation. The switch finger spindle has attached to it two ratchet wheels with the teeth cut in opposite directions. Each magnet has above its free pole a little armature, one end of which is hinged to a fixed point, and the other carrying a tooth that may engage in one of the ratchet wheels. The tooth of one keeper works in connection with one ratchet wheel, and the other keeper works the second ratchet wheel. A spring keeps these teeth free of the ratchet wheels, except at such times as when the magnets are excited. A supplementary piece of apparatus has to be employed in connection with this governor. When the current, or E.M.F., is too great this apparatus sends a current to one of the magnets; which causes it to engage the tooth of the armature in its ratchet wheel and to rotate and move the switch finger in one direction, thus putting resistance into the shunt circuit of the dynamo. When the current, or E.M.F., is too low, a current is sent to the other magnet; which causes the other ratchet wheel to turn in the opposite direction, the movement of the ratchet

wheel in all cases being effected by the motion of the rocking frame. The apparatus shows the details fairly well. When the switch finger has reached the end of its range, it automatically cuts the circuit of the magnet which has brought the finger in this direction, and consequently an accident is prevented. The springs at the top bring the current from fixed points to the moving parts.

The regulator for this governor is similar to the one described in the chapter on Switches (see Fig. 141, page 199) to be used with the author's automatic switch for turning the charging current on and off an accumulator. When this regulator is employed in connection with a governor, the current is sent to one or other of the rocking magnets, according as the E.M.F. is above, or below, normal ; and in such cases where constant current is desired, the coils upon the regulator are wound with larger wire so as to carry the main current. Under these conditions, the instrument will act in a similar way according as the current is above or below that for which the apparatus was set.

The chief difference, between a governor intended for putting resistances in and out of the shunt circuit of a dynamo and one for putting in and taking out counter E.M.F. cells, is that the contacts must be far larger, because the amount of current flowing at any time may be considerable. As a consequence, the working parts also must be larger and stronger. A governor of this kind may be used to reduce the number of cells in a battery supplying the lines during charging hours, or at any other times ; also for putting resistances in and out of any part of an installation. The particular uses to which a counter E.M.F. governor can be put will be more particularly dealt with in the next volume. The

apparatus designed by the writer was made by Messrs. Woodhouse & Rawson. Improvements in detail have been effected from time to time, until apparently perfection has been attained: by perfection is meant complete reliability. The main improvement introduced into this governor, since the block for Fig. 102 shown was made, is that the switch finger is now divided with a small resistance between the halves, so that, as the finger moves over the contacts, putting in or taking out cells, no appreciable spark is created. In all governors containing ratchet wheels the last working tooth of each wheel is filed away, whereby it becomes impossible for the switch finger to be pushed too far in the event of a portion of the apparatus sticking; which would otherwise cause some damage. It might be supposed that the little cut-out springs, situated at each end of the contacts, would cut the current when the finger reaches one or the other of them; but should these contacts not be properly set in the first case, they might fail. The filing off of a tooth on each wheel gives an extra safeguard. Another alteration in detail is that, instead of the current being led to the rocking magnets by means of flexible wire, which was found not to wear well, hinged levers are employed.

The counter E.M.F. governor is not run continually off the engine, as in the case of those intended for putting resistance in and out of a dynamo shunt circuit. Much wear and tear is thereby avoided, especially when it is remembered that this apparatus is of larger dimensions than the one used in the other case. Besides, at times when the engine is not running, this governor can regulate the E.M.F. on the lamp lines. The controlling regulation is obtained by means of an E.M.F. regulator such as is described in the chapter on Switches; and its

action upon the counter E.M.F. governor is the same as in the case of the governor described and shown in Fig. 101. But clearly the depression of one magnet-pawl or the other will not move the switch finger, unless the magnet-frame itself is rocked. The required motion is given in the following manner. At the same moment as that at which the magnet-pawl is depressed, a small motor is started, which revolves the pulley attached to the governor. This causes the switch finger to move until the pawl is released, in consequence of a current ceasing to flow through the magnets, by reason of the E.M.F. having become normal; since no current is sent from the E.M.F. regulator. The magnets upon the governor have a very high resistance, hence the amount of current required to excite them is very small. The object of this is not economy, but to prevent the possibility of the E.M.F. regulator contacts being burned up by excessive sparking. Therefore, it will be evident that the E.M.F. regulator would not be suitable to pass a current to a motor at the same time as it does to one of the governor magnets. The motor is started in this way. The wire attached to the swinging finger of the E.M.F. regulator is cut and each end taken to the ends of a coil upon an electro-magnet, which is wound with a high resistance. This magnet forms part of an automatic switch. It draws down an armature, to which is attached a series of levers, the last one carrying a copper prong which, when the system of levers is drawn down by the magnet, dips into a mercury cup, and thus starts the motor. This automatic switch is practically a relay. The only difficulty encountered in constructing the relay is the very small amount of current employed to excite the electro-magnet, and the large amount of

motion which must be given to the copper prong in order to break the motor current; hence the insertion of the system of levers. The magnet acting completes the circuit, and a spring withdraws the prong from the mercury cup. It will be noticed, therefore, that every time the current is sent to one of the governor magnets, it passes on its road through the motor relay, so that any

Fig. 102.—Salomons' Large Governor.

spark produced at the contacts of the E.M.F. regulator must be very small; in fact, it is not visible. Upon this relay, as well as upon the governor itself, adjustment screws are to be found for adjusting the spring tensions as well as for limiting the motions. The magnet coils in all cases can be removed with the greatest ease, in the event of the winding at any time giving way, and a spare coil can be fixed in place in the course of two minutes.

Where governors are inserted in an installation, duplicate parts are very essential; for much inconvenience is avoided, and by some unknown law the fact of possessing a duplicate part appears to keep everything in order, in somewhat the same way as a pension gives its recipient a long life.

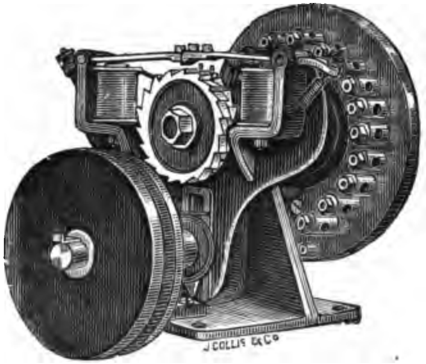


Fig. 103.—Counter E.M.F. Governor (Back View).

The counter E.M.F. governor is shown in some detail in the following plates.

The front view is illustrated in Fig. 102. The finger is now divided.

Fig. 103 shows the back view. In this one the

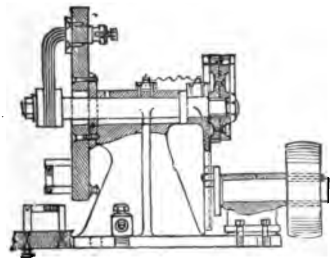


Fig. 104.—Counter E.M.F. Governor. Section.

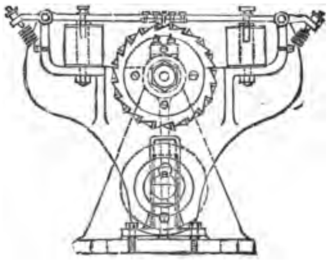


Fig. 105.—Counter E.M.F. Governor. Back Elevation.

terminals are seen for attaching the cables leading to the cells. One end of the main lead is attached to the end cell, and the continuation of this lead is attached

to the terminal on the base, which is seen in Fig. 104 of the front elevation.

Fig. 104 is a section of the governor, and Fig. 105 is a diagram of the arrangements as seen from the back. To render this plate more distinct, the switch portion is removed.

It may be generally pointed out that the motions here employed are convenient in all types of apparatus where a rocking movement has to be converted into a circular motion ; and it will be further observed that the first motion, *i.e.* from the pulley, is circular also.

There can be no question that the insertion of governors of the forms described, or others equivalent in design, produces the most satisfactory results that can be obtained. This, in practice, means charging an accumulator under the most favourable conditions in the shortest space of time, and securing a constant pressure in the lamp circuit. Besides deriving these advantages, the chief anxieties connected with electric lighting are removed.

CHAPTER V.

SWITCHES AND SWITCH-BOARDS.

WHEN a house is wired, certain apparatus is necessary before the electric energy can be employed. Briefly it consists of the following: A switch-board, which should have placed upon it the requisite control switches and fuses for the whole building. For every floor there should be a similar switch-board, but smaller in size, in order to command the circuits on the floor where such board is fixed. Beside these, switches for the lamps, ceiling plates, brackets, fuses, wall-connectors and other minor matters are required. Measuring instruments should also exist; one to meter the energy in the same way as is done with gas, another to measure the current flowing at any moment, and a third to show the pressure. In describing the various forms of such apparatus, switches and switch-boards will be first considered and dealt with in this chapter.

SWITCHES.

The switch may appear perfect when examined in a show-room, and prove the very reverse when put into practice.

At the present moment there is no perfect switch made, and on this point the electric light is at a disadvantage when compared with gas. A gas tap

suffers no wear and tear worth mentioning, and may be regarded as an apparatus which will last out many generations. The electric switch, on the other hand, is slightly deteriorated every time it is used, not only from the spark created, but from the jar the snapping action produces. The result is that, in a great number of cases, it becomes necessary to adjust or repair a switch from time to time, especially the small ones used in connection with lamps which are in constant use. Since the holes of the fixing screws are very close together, and these screws, as a rule, obtain their hold simply by entering the plugs driven into a plaster wall, a frequent removal renders the wall rotten at these points; which becomes a source of great annoyance. Again, should a switch upon a distributing board require adjustment or repair, its removal is generally difficult. In order to obviate these inconveniences the author has recently arranged to have all switches made to his specification, with the condition that there shall be no screws or springs under the base of the switch, excepting those which hold permanent parts requiring no adjustment. The finger and spring, or springs, may therefore be removed at any time without the necessity of taking down the switch; an advantage which cannot be overrated.

Switches may be classed under three heads:—

1. Main switches, *i.e.* those required to make, and break, large currents.

2. Lamp switches, for making and breaking small currents.

3. The above two kinds, with a snap action added.

The following are the essentials which are necessary in a good switch. For carrying large currents the

contacts must have ample surfaces, and between the latter there should be a good pressure. The switch, notwithstanding the pressure, must be light to work with the hand. The base should be fireproof and of a material as perfectly non-conducting as possible. It must also be strong and not brittle. All parts liable to wear should be simple, and capable of being easily replaced without the aid of skilled labour. The whole of the working portions should be situated on the front. Any portion liable to become warm, in consequence of wear or from any other cause, should be easily reached by the hand for the purpose of observation. In the case of double-pole switches it is advisable to mount each switch on a separate base; and the bases, in turn, on strips of ebonite, vulcanite, or dry shellac varnished or polished wood, so as to prevent all possibility of leakage from one main to the other. This is especially necessary when slate is used for the base, since many samples are found to possess slight conducting properties. The lever joining the two switches for working them simultaneously must also be very perfectly insulated, so that the highest possible resistance may be given between switch and switch. Earthenware is now largely used for switch bases, and great care is necessary that these should not be cracked or broken in screwing them to the wall or other support. As earthenware bases are rarely flat, it is generally advisable to place a thin piece of felt under the base before screwing up. Many breakages would be avoided if this method were followed.

There should exist adjustments for taking up wear. Since on breaking the current a spark is produced and metal is burned, the construction of the contacts should be such that any roughening of the metal, in consequence

of the spark, shall not interfere with the smooth working of the switch. Any screw-heads, nuts, or other metallic parts which may be found under the base should be countersunk, and the sinks filled with paraffin wax to the level of the base. When slate is employed, a suitable piece should be selected and then boiled in paraffin wax. Often it is the practice to put the slate straightway into the molten wax, the result being that the slate is liable to crack. The best course is to warm the slate first and then dip it, or else to place the slate on the paraffin wax and heat the whole up together. The object of this waxing process is to fill up the pores of the slate, and thus prevent moisture entering it. With the better class of apparatus enamelling is generally resorted to. Marble is often employed in the place of slate. The handle, of whatever shape, should be insulated from all portions which carry current.

All the requirements, mentioned in connection with switches intended for large currents, apply with equal force to those intended to be used for small ones. In the case of large switches, there is always room to carry the moving contact to a distance sufficient to break the spark; and, as a rule, covers are not placed over them. But with small switches, which have covers, further precautions have to be taken. It is the general practice to put what is termed a snap action, so that, when the current is turned off, the moving portion is automatically and quickly carried to a position of rest, so that the spark is cut with certainty and cannot be left in a position to arc. This is usually effected by means of springs. It is essential, in the event of the springs failing from any cause, that the handle should move the switch finger to a safe distance by a positive action.

Switches, which do not possess this positive action (*i.e.* wherein it is not possible to turn the switch off properly by hand, in the event of the spring failing) are unsafe. The cover should be fireproof and, if of metal, well insulated from all the metallic portions of the switch. The cover also should be capable of easy removal, in case of need. Many switches for carrying large currents are made with a snap action, but for them it is of less importance than for small currents. Switches, which are kept to the position of "ON" simply by the pressure of the contacts, should be avoided. When these wear, they will have the property of extinguishing the lamps of their own accord and without notice.

Again, many switches, which appear perfect when new, are the very reverse when subjected to wear and tear. A switch should, therefore, be examined most critically. It must be remembered that the choice of a lamp switch is of great importance, apart from any considerations of safety. If the owner of a house makes a mistake in the choice of a switch, it is an expensive and a troublesome proceeding to make a change afterwards: it is not the mere matter of replacing one little bit of apparatus, but it involves a revolution throughout the house.

Some switches are made to snap *on*, as well as *off*; but there is no particular advantage in this. When the circuit is "made" with the current pressure in general use for lighting purposes, no apparent spark is formed. It is only on breaking the circuit that a large spark is created, the size and length of the spark depending upon the E.M.F. and the amount of current flowing at the time; and it may be regarded as the momentum of the current, the current continuing to flow during the cutting action. It may seem strange that, with a given E.M.F. which can

produce only a short starting spark in air, it is possible for the breaking sparks to have variable lengths, depending practically on the amount of the current flowing. The reason is this: with a large current the quantity of metal burned is greater than with a small current. The metal is volatilized, so that the spark is spurious; *i.e.* it does not jump across the large gap, but travels through the metal vapour from particle to particle. This may be proved in a very simple way: if a bellows is kept blowing at the point where the spark is created and a large current (at 100 volts) is cut, scarcely any visible spark is formed. To reduce this action as much as possible, numbers of switches have been made. Amongst the most successful are the little-used "Many-break" forms of switch, where the spark is divided up into a number of small ones by breaking the current at many points at the same time. The spark can be reduced also by using a step-switch, with a resistance between each step, whereby a current is diminished gradually, instead of being suddenly broken. The Siemens' "Carbon Last Break" form of switch, which will be described, is one of the best for preserving the contacts bright. With alternating currents a sparkless switch can be made by producing at the moment of breaking a counter E.M F. to that of the current. The same method could be employed for direct currents with counter E.M.F. appliances, or better with condensers; but the apparatus would be complex and expensive.

In every instance, switches for large or small currents should be placed within easy reach. In the case of large switches, covers are not usually supplied. They are either put up without any cover at all, or placed in a glass case. It is sometimes desirable to protect a switch employed

for breaking a large current very effectually, especially when such switch is fixed in buildings made of wood or where the contents of a room are exceedingly inflammable. The simplest way for making such a cover is to place over the switch a wooden lid, lined with asbestos sheet the thickness of, say, an eighth or a quarter of an inch. The handle may be allowed to protrude through the case. This cover may be in one or more pieces, according to the make of the switch.

It is possible to render wood fireproof, by impregnating it with tungstate of soda; and, when this is done, it may be used to replace slate or porcelain, but the latter are to be preferred. Many kinds of earthenware and artificial stone have been produced, with a view of obtaining the advantages which slate gives without its defects. Serpentine has also been much used. Ebonite, though a first-class non-conductor, is injured by heat, and therefore not very suitable for switch and cut-out bases. This material also becomes moist on its surface by the sulphuric acid which separates from its substance, chiefly in the presence of light, producing surface conduction and injuring any metal which may be attached to it. Notwithstanding these drawbacks, which may be partially removed by varnishing, the use of ebonite is found to be an advantage in very damp situations; and it is necessary that all metal portions mounted on it should be large, so as not to heat. Vulcanite fibre is not much inferior to ebonite, but is unsuitable for damp situations; since the leakage produced by moisture tends to carbonise the surface, due to the presence of salts in the substance, thereby impairing its good insulating properties. Professor Vernon Boys has recently discovered that quartz is a remarkable insulator, even

when the surface is moist. This substance is costly to work, but in some cases where great difficulty exists in preventing leakage, it may, notwithstanding the expense, find employment.

The following are examples :—

A very favourite form of switch, largely in use at the present time, was devised by the author when these apparatus were in their infancy and but little importance was attached to switches. He was unable to find a

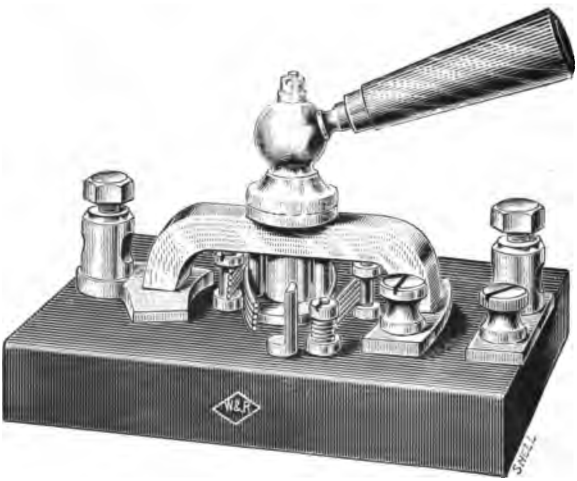


Fig. 106.—Woodhouse & Rawson's Snap Action Large Switch.

satisfactory form of switch, and, in consequence, was compelled to design one. They were first made by Messrs. Woodhouse & Rawson. Fig. 106 is an illustration of the main switch of this spring-arch type, with snap action.

Fig. 107 shows a switch, with two steps. These can be made with as many more steps as may be desired.

Fig. 108 illustrates a similar switch of the double-pole type, with snap action.

Fig. 109 is a lamp switch, with snap action.

Fig. 110 is a snap-action switch for larger current. Some of the details differ from those of Fig. 106.

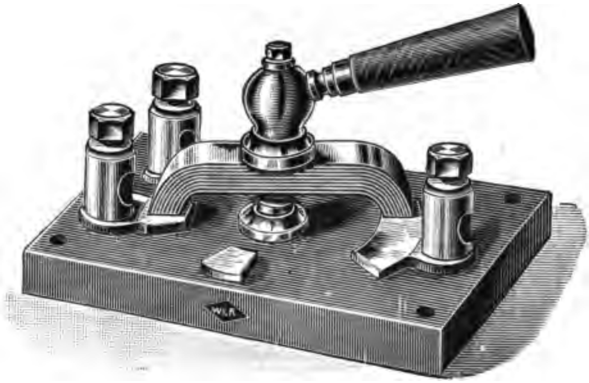


Fig. 107.—Two-way Switch.

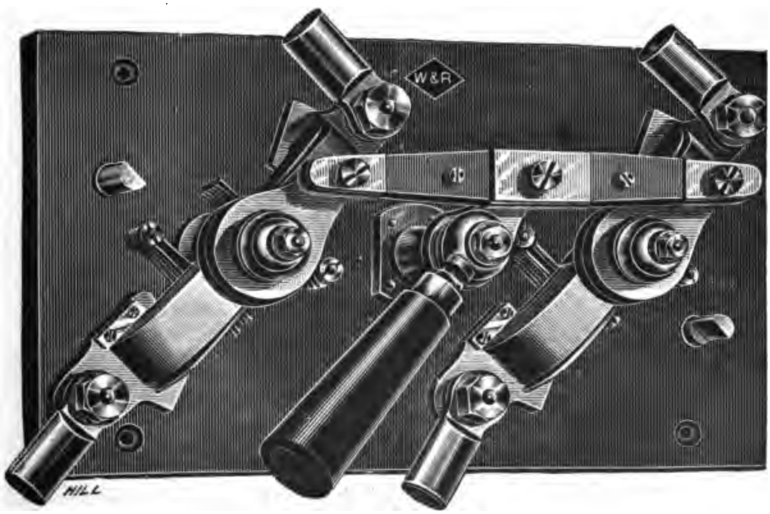


Fig. 108.—Double Pole Switch.

Fig. 109.—Two-way 5-Ampere "G" Switch.

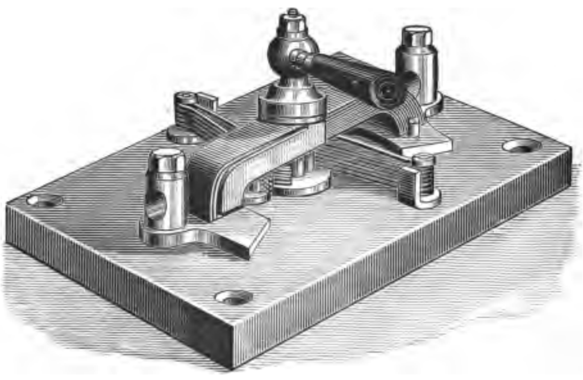


Fig. 110.—Snap Action Switch.

Fig. 111 shows the Broomhill combination switch. This is capable of being used as a wall-connector as well as a switch. In this arrangement the plug, after its insertion, is pushed to the right or the left, as the

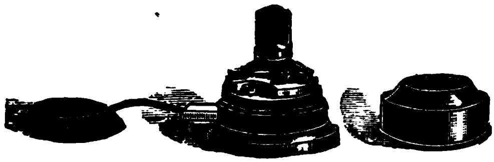


Fig. 111.—Broomhill Combination Switch.

case may be, for putting on, or off, current. The switch itself commands its own lamp or lamps, and independently of the plug.

Fig. 112 illustrates a many-step switch, for putting resistances in and out.

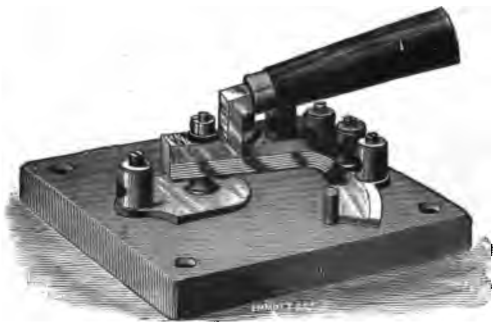


Fig. 112.—Many-step Switch.

Figs. 113 and 114 show the exterior and interior appearance of a switch suitable for a converted gas-fitting.

Fig. 115 illustrates Drake & Gorham's switch. Although it has not a snap action, the equivalent motion is produced, because of the sudden release of the finger

as it passes out of the split rings. The muscles of the hand and arm in this case act as if a spring were placed in the switch.

Fig. 113.—Switch for Gas Fitting.

Fig. 114.—Interior of Switch for Gas Fitting.

Fig. 116 is the "Paiste" switch, with cover on and cover off. In this, the handle must always be turned in the same direction; the first half turn putting *on*, the next putting *off*.

Fig. 117 is a switch so arranged that, when the knob is pressed in, the light is put on; and when pressed in a second time, the light is put off.

Fig. 118 is the Browett pull switch. The action is similar to that described in the last case; only instead of pushing a knob, a lever is pulled with a cord. There is no need with this switch to bring the wires below the cornice. Other switches of this type exist, one being identical with the author's ratchet-wheel pattern introduced in 1884.

One of the best and most convenient switches in the market is made by the Edison & Swan United Co. In

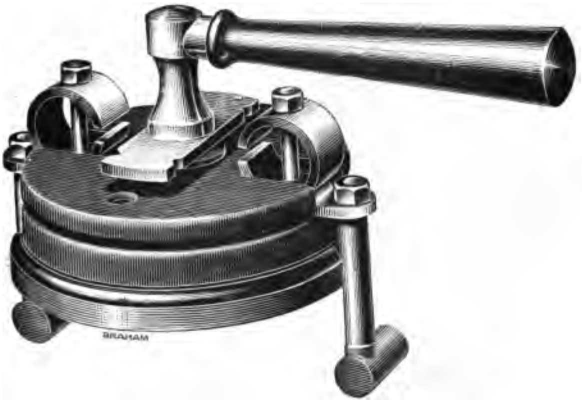


Fig. 115.—Drake & Gorham Switch.

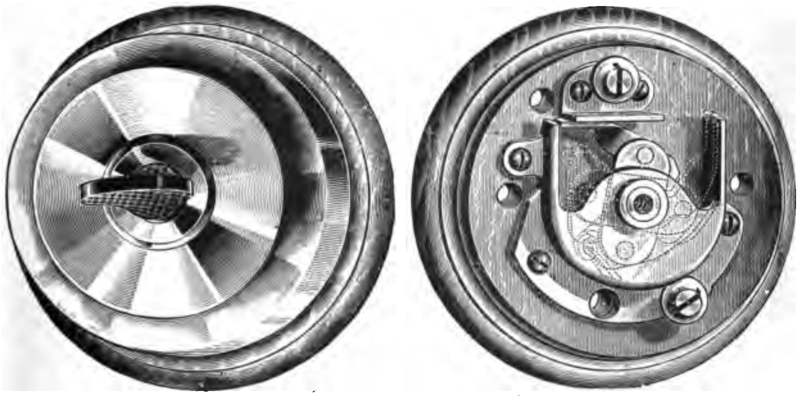


Fig. 116.—The Paiste Switch.

the last edition of this book the author expressed himself as being dissatisfied with the mechanism of this switch, as made at that time; in fact, it was a dangerous

piece of apparatus. The Company have since effected the suggested improvement, which obviates the disadvantage which formerly existed; the switch has now become an excellent and a safe piece of apparatus, and is used to an enormous extent.

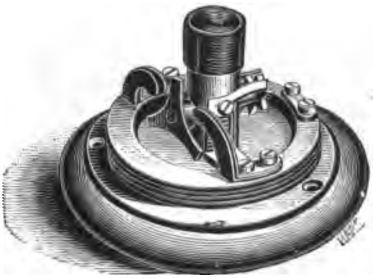


Fig. 117.—Single-light Push Switch.

Fig. 119 shows, full size, a switch suitable for 5 amperes.

Fig. 118.—Browett Pull Switch.

Fig. 120 is the same switch, with the cover off. The Company call this type the Tumler.

These switches have now a positive action, whereby

the hand is made to break the current in moving the handle, should by any chance the spring fail to act.

Fig. 119.-- Edison & Swan Tumler Switch (Full Size).

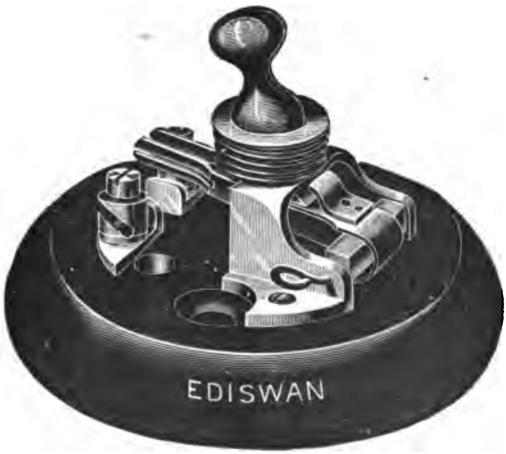


Fig. 120.--Edison & Swan Tumler Switch (Full Size—Cover off).

Fig. 121 is an Edison & Swan type of switch for large currents.

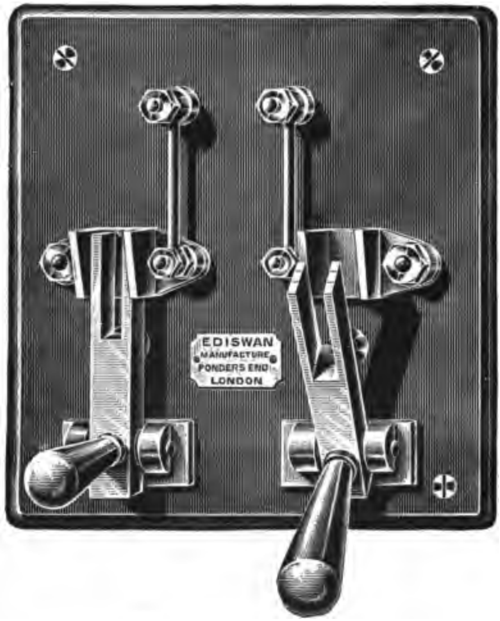


Fig. 121.-- Edison & Swan Two-way Switch.

Fig. 122.—Dorman & Smith Double-break Single-lamp Switch.

Fig. 122 shows a Dorman & Smith double-break single-lamp switch.

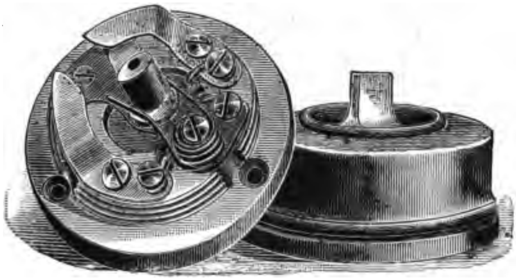


Fig. 123.—Two-way Switch (by Dorman & Smith).

Fig. 123 is a Dorman & Smith two-way switch.

Fig. 124.—Siemens' Carbon Last Break Switch.

Fig. 124 shows a Siemens' carbon last-break switch, made by Messrs. Dorman & Smith, under license. In

this case the metallic portions of the switch separate, while two pieces of carbon, in the shape of rollers, are yet in contact; one piece of carbon moving with the switch handle, the other fixed as shown in the figure.

Fig. 125.—Acme D. P. Switch, Snap Action.

As the handle is turned farther, the carbons part company and the spark takes place between them. Consequently, the metallic portions of the switch are never burned and always remain bright. The carbon does not burn away for a very long period, and can be renewed at any time for a nominal sum.

Fig. 126.—Acme 250-ampere Switch.

Fig. 125 gives a view of the acme double-pole main switch, with snap action. This shows the improvements suggested by the author. The whole of the working parts are situated on the front of the slate, which permits of all repairs and adjustments being made without the necessity of removing the switch from the wall.

The Acme Electric Works also make a very compact and good form of switch for large and small currents.

Fig. 126 illustrates one of these switches suitable for 250 amperes. The contacts in this case are end contacts.

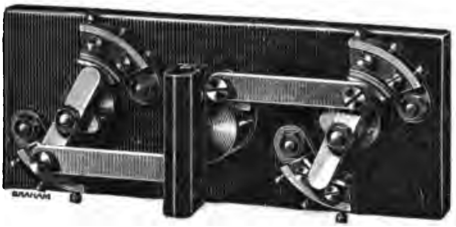


Fig. 127. – Acme Coupled Switch (End Contacts).

Fig. 128.—Double Pole Switch.

Fig. 127 shows a double-pole switch of this type.

Fig. 128 is a good form of double-pole switch, made by the General Electric Company.

Fig. 129 is another double-pole form.

Fig. 130 illustrates a single-pole switch, which is very smooth in working.

Fig. 131 is a well-known form of switch made by Messrs. Drake & Gorham.

There are hundreds of other forms of switches in the market, but the leading ones here illustrated practically represent the main types in present use.

Fig. 129.—Double Pole Switch.

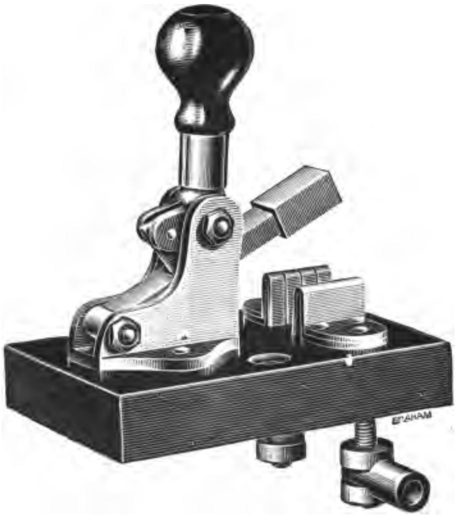


Fig. 130.—Link Switch.

Besides the numerous forms of switches already spoken of and illustrated, there are others, all of which are found convenient in special cases; indeed, there are few existing installations where such special cases do not occur.

The long-distance magnetic switch is one which can be worked at a distance. This is generally effected by one or two press buttons, from which wires lead to the switch, which may be at any distance from the press-buttons, and actuates electrically some form of apparatus for moving the switch.

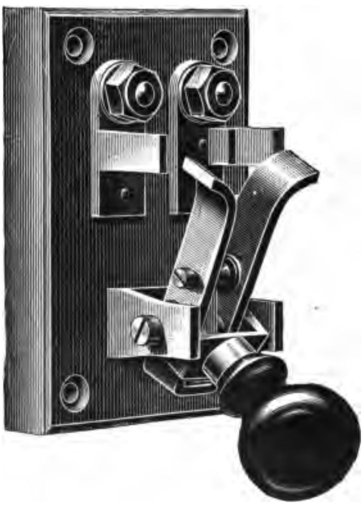


Fig. 131.—Drake & Gorham Switch.

Figs. 132 and 133 represent a switch to be employed with high-tension currents, which are dangerous to life. Fig. 132 shows the switch closed, and Fig. 133 open. It will be noticed that the switches work by pulling porcelain knobs, which are attached to cords. The spark created by a high-tension current draws out to a great length. The snap action, therefore, must be rapid and the separation large. Such switches might be considerably improved by a little compressed-air apparatus worked by the switch; such, for instance, as a piston in a cylinder, or a pair of bellows to blow out the spark. Flaps are sometimes used to cut the spark. The

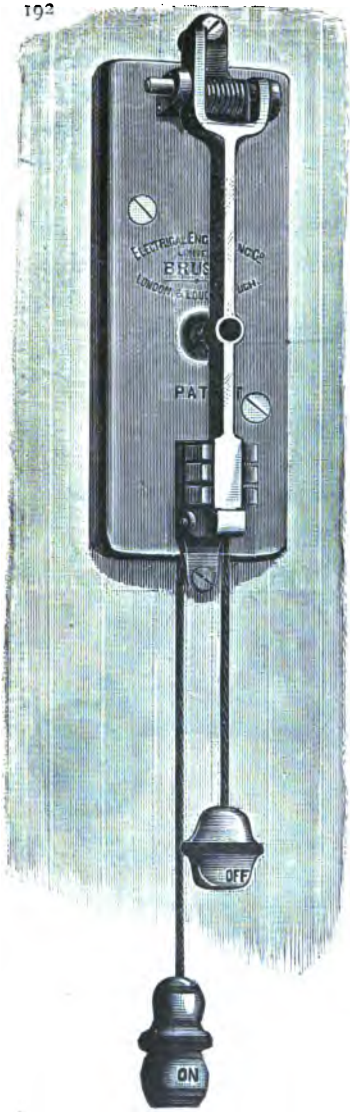


Fig. 132.—High Tension Switch.
(Switch closed.)

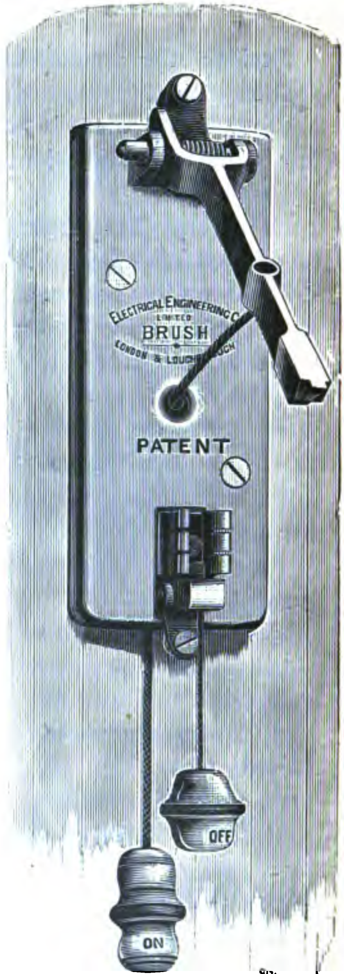


Fig. 133.—High Tension Switch.
(Switch open.)

reason for the length of spark is that, after breaking, there is still a path for conducting the current between the fixed and the movable portions of the switch, through the metallic vapour which is formed by the burning of a small amount of metal at the moment of breaking. The tension of the current being high, the sparking continues to take place after breaking, from molecule to molecule of the metallic vapour. This effect is also considerable in the case of low-tension currents, when mercury switches are employed.

When a voltmeter is used for two sets of mains, it is better to cut both wires from one set of mains before connecting the instrument to the wires on the other mains.

Fig. 134.—The "W. & R." Voltmeter Switch.

Fig. 134 illustrates such a switch which is two-way, but they are frequently made with more ways. An example of the use of such a switch in an ordinary installation is the following, where one voltmeter is employed to measure the pressure of the current charging the accumulators and the pressure on the lines to the house.

It has been pointed out in Vol. I. that the dynamo should not be turned on to an accumulator until a certain pressure has been reached, such pressure being slightly in excess of the pressure given by the accumulator. It is also evident that, when stopping the dynamo, one or

both leads must be cut from the accumulator before the voltage of its current falls too low. When the turning on and turning off of a dynamo from the accumulator depend upon a man watching a voltmeter, accidents continually occur, and to guard against this possibility automatic switches are largely employed.

There are several methods of working these switches. The differential method of Mr. Nevile is one in which an electric magnet is so arranged as to have two currents

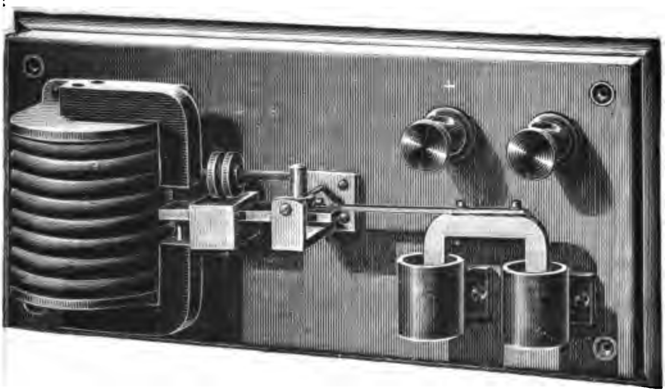


Fig. 135.—The "Nevile" Patent Automatic Accumulator Switch.

flowing round it in independent coils, one from the accumulator and one from the dynamo. As soon as the pressure in the dynamo circuit exceeds that of the accumulator, the dynamo is connected to the accumulator by means of a mercurial switch; and the contrary action takes place on stopping the dynamo. Fig. 135 indicates this switch.

In Holmes & Vaudrey's patent automatic switch there is a solenoid, through which the shunt current of the dynamo passes. The main current also passes

round the instrument when the circuit is completed. The switch is a mercurial one, and is shown in Fig. 136.

With the last two forms of automatic switch, if by any chance the switch should fail to act when the cells are nearly charged, and the current should flow from the accumulator to the dynamo, the action will continue. For this reason the writer prefers automatic switches which are not differential in action.

Fig. 136.—Holmes & Vaudrey's Patent Automatic Cut-out.

Fig. 137 illustrates the Barber-Starkey automatic cut-out for accumulators, which is somewhat similar to the usual forms, but

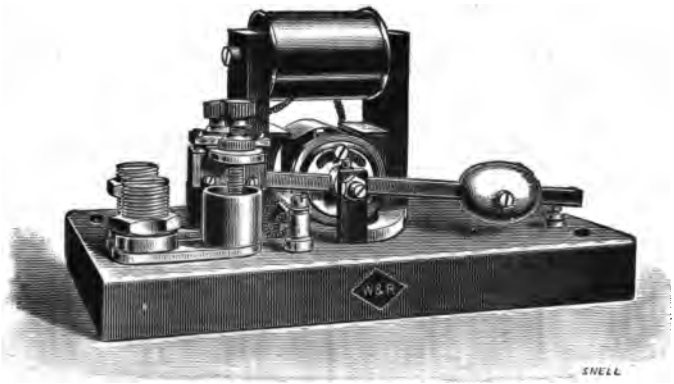


Fig. 137.—" Barber-Starkey " Automatic Accumulator Cut-out.

has the addition of a weight to enable the cut-out to be rapid in order to diminish the spark when the prongs leave the mercury cups.

Another form of automatic switch to use with an accumulator is given in Fig. 138. It consists of a horseshoe electro-magnet, hinged at the yoke. When the E.M.F. at the dynamo terminals is sufficiently high, the poles of this magnet draw together, which causes a block of metal to be pushed between two springs, thus completing the main circuit. The diagram also shows the connections.

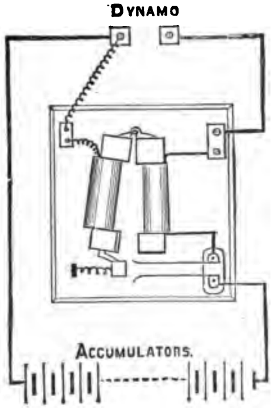


Fig. 138.—E. P. S. Automatic Switch.

A form of automatic switch is illustrated in Fig. 139. It will be observed that the finger rests either upon one spring or upon another, according as the core is drawn into the solenoid more or less, which depends upon the E.M.F. of the circuit. The main current passes through the movable finger and

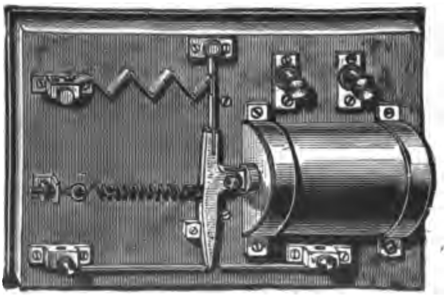


Fig. 139.—Automatic Regulator Switch.

is connected with one of the main circuit terminals by means of a zigzag strip of copper. The object of this

switch is to enable a certain number of cells to be cut out of the circuit when the E.M.F. is too high. Such a switch is useful in a private installation to cut a few cells off the house lines during charging hours. It is also used in train lighting.

Another automatic switch is made for a current alarm. There are many forms for this purpose, but in principle most of them consist of an armature or a core, which is drawn down, against a spring or a weight, by an electro-magnet or a solenoid which carries the main current. When the excess current is reached, draw-down piece makes a contact to ring an electric bell or gives some other signal. The author suggested the following arrangement, which has been used in many cases for preventing the main fuse from going in a house. An automatic switch of the kind just described is made to insert a very large resistance in the house circuit when the excess current is reached, in consequence of too many lamps having been turned on. Immediately all the lamps will appear dull, which is the warning; instead of the main fuse going, which is always a source of annoyance. As soon as some lamps have been turned out, reducing the current to the normal, the switch ceases to act, and the lamps burn bright again.

One form of alarm apparatus is shown in Fig. 140, with the connections. In this instance the main current passes through two compound strips of metal, consisting of two plates of different metals soldered together. These strips are joined at one end, the other extremities of the strip being attached to the circuit, so that the current flows down one strip and returns by the other. When the current exceeds a certain limit, the strips are over-heated and become curved; thus the free

end comes in contact with a set screw, which is adjustable, and thereby a circuit with an electric bell is completed.

In order to prevent the possibility of a current becoming reversed, whereby the cells discharge into the dynamo (which is apt to occur in small installations),

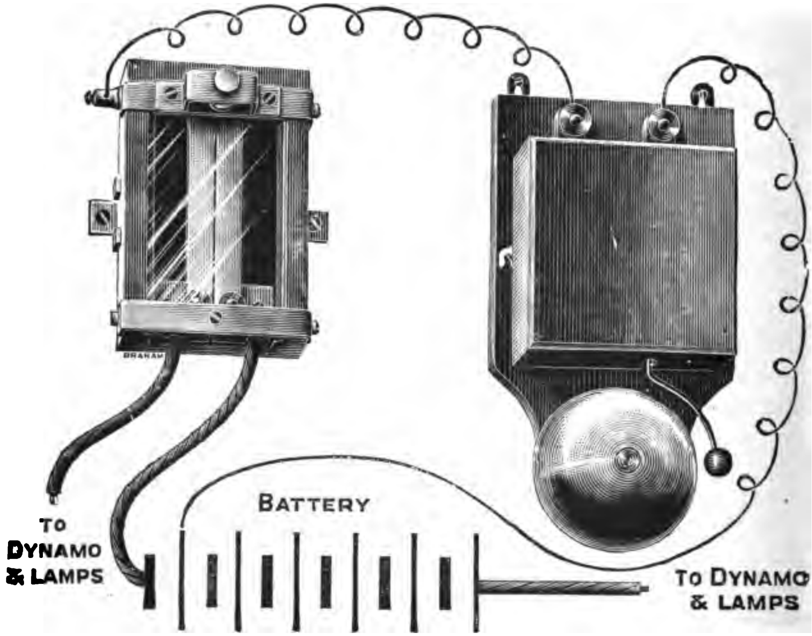


Fig. 140.—Automatic Contrivance for Giving Notice when Maximum Working Current is Reached.

the author devised a piece of apparatus to remedy such a mishap, should it ever arise. This instrument he calls an "anti-reverser." It consists of a thick coil of wire capable of carrying the usual charging current. In the centre of the coil swings vertically a permanent magnetic needle. To the arbor of the needle is attached

a balanced arm ending in two prongs, each of which dips into a mercury cup. The charging current, on its road, passes through the coil and these cups, which are electrically connected by the prongs when they dip into the mercury. So long as the charging current passes the right way, the magnetic needle tends to move in such a direction that the fork remains in the mercury cups. But, in the event of a current of two or three amperes passing from the cells to the dynamo, the magnetic needle moves in the opposite direction, causing the

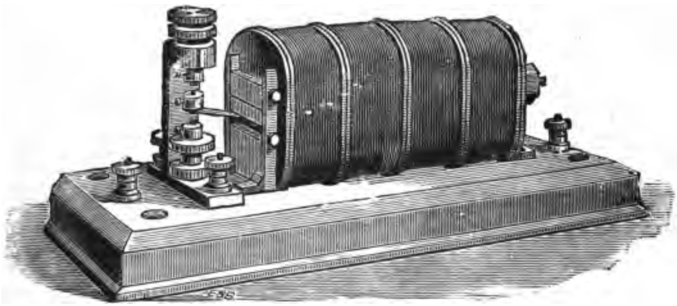


Fig. 141.—E.M.F. Regulator (Repulsion).

current to be cut in consequence of the fork being raised out of the mercury cups. An adjustment exists for any pre-arranged current. A suitably arranged weight assists in cutting the current rapidly.

The automatic switch for charging accumulators, as devised by the author, is the following :—

This instrument consists of the E.M.F. regulator (Fig. 141), which sends a current to a mercurial switch (Fig. 142) when the E.M.F. is sufficiently high, and another current when it falls below the proper amount; thus making or breaking, by means of this controlled switch,

the dynamo and accumulator circuit. The switch is made two-way to permit the current from the dynamo, when the charging circuit is broken, going through a resistance, passing a current equal to that for charging the cells, whereby shock to the machinery is avoided. Hence no difference is produced in the load at the moment of putting the current to the accumulator. These instruments have never failed in the author's installation, and probably no existing automatic switch is so sensitive and reliable.

The detailed construction of the E.M.F. regulator (Fig. 141) is as follows: A coil having a resistance of about 4,000 ohms surrounds two soft-iron bars, one movable horizontally, being pivoted. For convenience the coil is divided into four sections, and is joined, voltmeter-fashion, at those two points upon the mains where the changes of E.M.F. are to actuate the instrument. The bars of soft iron are bent thus ___/‾‾‾ in side view and cross one another, appearing so ═×═ Where these cross, the iron is cut away to permit of their being placed in this manner, so that the bars may face one another throughout their length. It will be noticed that, when a current passes through the coil, the whole system will become magnetic; and, in consequence of the peculiar form given to the bars, the movable one will be displaced by repulsion and not by attraction (a principle proposed by Mr. Davies), since the polarities at each end of the instrument are the same for both bars, the effect at one end being doubled by that at the other extremity. The movable bar at one end carries an adjustable weight similar to that of a steelyard. At the other, it carries a short rod to which is attached a contact arrangement consisting of a holder with a thick wire of

platinum in it. This movable swinging contact-piece may touch an upper or a lower platinum contact fixed to the base of the instrument. Its action is thus, in a 100-volt installation: if the weight is so adjusted that when 110 volts is the pressure of the current traversing the coil, then the swinging contact touches the lower fixed contact, and a current passes through the movable

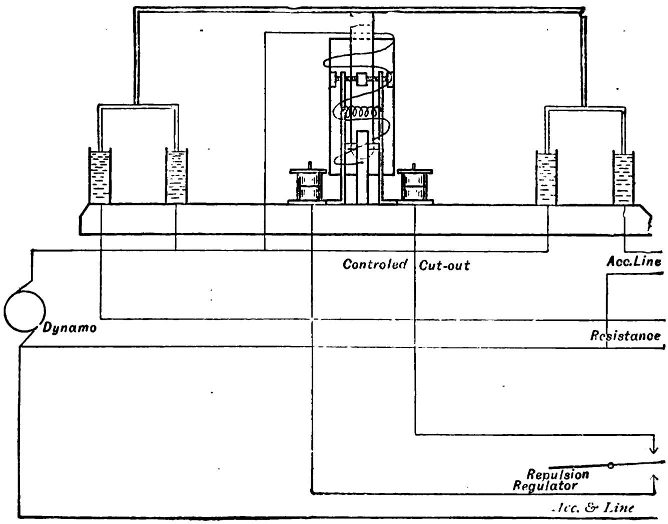


Fig. 142.—Controlled Switch, showing Connections.

arm to this fixed contact, and onwards through a wire to one end of the coil upon the magnet forming part of the controlled switch, which has the other extremity connected with the opposite lead, thereby causing the switch to act and place the dynamo on to the accumulator. When the E.M.F. falls below 108, the repulsion between the fixed and movable magnets is no longer powerful enough to overcome the weight, and the mov-

able contact comes against the upper fixed contact, and a current is sent to the magnet coil on the controlled switch through another wire, which causes it to act in the reverse way, and the dynamo is taken off the cells. All contacts are platinum, for this wears far longer than any other material and does not oxidise in the air, so their surfaces remain bright. The weight may be adjusted for the instrument to work at any other E.M.F., but if employed on circuit of very low pressure, naturally the coil would be wound with a lower resistance. The *difference in the pressure* between the putting on and taking off the cells from the dynamo is regulated by adjusting the distance between the upper and lower fixed contacts, which permits of the movable contact having a longer or shorter free swing. The longer the swing the greater will be the difference. It is evident that, when this regulator is used for charging purposes, the whole time this operation is continuing the swinging contact will remain touching the lower fixed one, and *vice versâ*.

Fig. 142 is a general diagram of the controlled switch or cut-out, showing its connections with the E.M.F. regulator. Its action is identical with Cunynghame's magnetic cut-out, except that it is a two-way switch. When the switch is on the one side, the current is put from the dynamo to the cells, and when on the other, from the dynamo to the resistance. It must have been observed, in the description of this cut-out, that when the magnet has drawn the armature towards its pole through a certain distance, it is essential that the current in the magnet coil shall be cut. To fulfil this condition in the controlled switch a special arrangement is added,

in consequence of the instrument being two-way. This addition consists of two contact levers, which make or break the magnet circuit when required, and is accomplished at the proper times by the moving armature.

The current flows through the coil of this instrument only at the moment of action, and not at any other time. The writer found considerable difficulty in making contacts for the E.M.F. regulator which would not wear away rapidly. After numerous experiments the following method was found successful.

If the moving contact was made of platinum about $\frac{1}{16}$ of an inch in diameter, and the fixed contacts considerably larger in section, say $\frac{1}{4}$ of an inch diam., the wear and tear became inappreciable. When the contacts were of equal size, the platinum required frequent renewal. It is possible that other experimenters have come to similar conclusions.

The E.M.F. regulator is also used as a governing instrument, and it was referred to when governors were dealt with.

Fig. 143 is a form of switch to be employed for adding a few, more or less, cells to the battery, and for adding to, or subtracting from, the lamp circuit a few cells. The application of many of the apparatus described will be referred to later in the proper place.

Any switch intended for adding cells to a circuit, or subtracting them, may be made in one of two ways. Either the contact pieces must be placed sufficiently apart that the moving finger in passing from one contact to the next breaks the current, or the contacts may be placed sufficiently close together that the finger passes to the next one before leaving the first. Neither of these simple conditions is desirable. In the first case, if a

current is flowing at the time, the current is cut and a large spark is created before the current is re-established. In the second case it is evident that any cell or cells which may be connected to these contacts become short-circuited. A large spark consequently is made when the finger leaves the first contact, which would render the apparatus soon unworkable; besides which the cell or cells would be injured. If, between the two contacts,

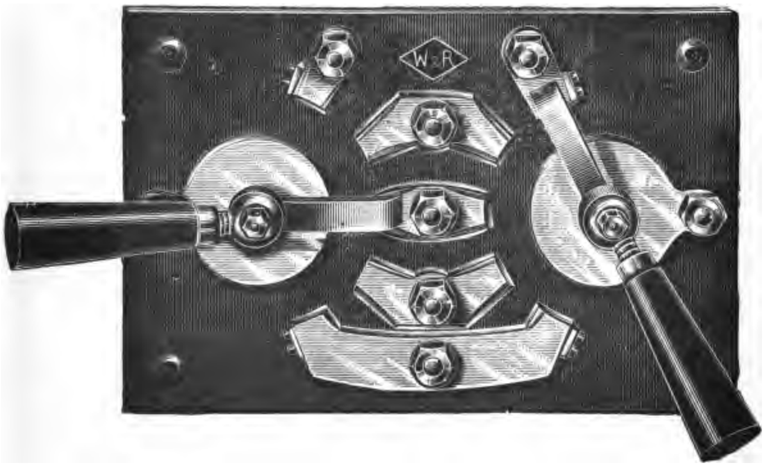


Fig. 143.—Charge and Discharge Switch.

several contacts are added, with suitably adjusted resistances between each, it will be possible to move the switch finger from the first to the second contact, passing it over the intermediate ones, without creating a spark worth mentioning. Indeed, if the resistances are adjusted to the current flowing at the time, there will be no spark. Professors Ayrton and Perry simplified this method by the employment of two fingers placed close together, instead of one with a small resistance between

them ; this resistance being wound on a bar of vulcanite fibre attached to the switch handle. The resistance comes into use only when the fingers are moved and are upon adjoining contacts. When a shift is made, both fingers must stand on one contact-piece. It is rare that more than one or two cells are put on or off at each step. Consequently, one or two cells are short-circuited through this resistance during a shift, and no appreciable spark is created. The principle of this switch is shown in Fig.

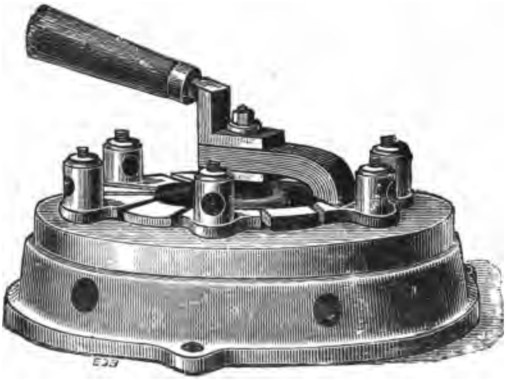


Fig. 144.—Cell Switch.

145, although this particular diagram illustrates a compound switch with two such double fingers moving about one centre. This form of switch has been simplified by Mr. Herbert Davies, and is shown in Fig. 144.

In this case the finger is not divided, but there is a dummy contact between the true ones. In the base, made of cast-iron, is placed a number of small resistances, which are connected between every dummy and true contact. The switch finger, therefore, in passing from contact to contact travels over a dummy one; and from

the figure it will be observed that, in all positions of the finger in passing from contact to contact, there will be a resistance between any cells connected to the true contacts.

Other forms have been devised which need not be referred to.

In order that the extra cells of an accumulator shall not lie idle, a method was contrived by the author for

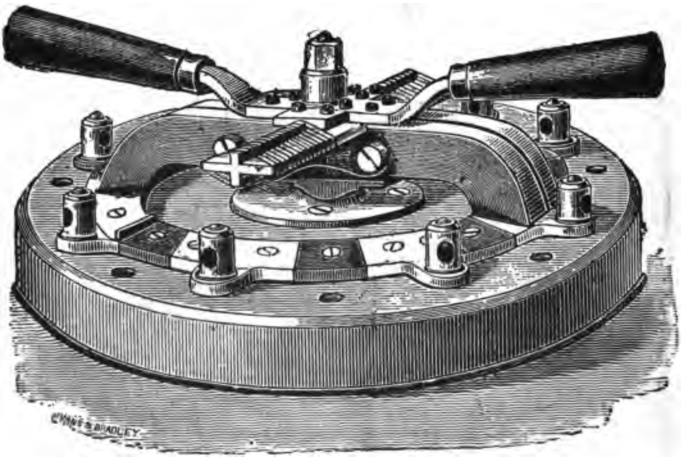


Fig. 145.—Compound Switch.

placing such cells in parallel with the last ones of the battery for ordinary work. A special form of switch for shifting these extra cells from parallel to series is shown in Fig. 145.

A diagram of the connections to this switch is shown in Fig. 146.

The diagram (Fig. 146) needs no explanation. It will be only necessary for the reader to trace the connections to the various positions of the switch fingers in

order to understand it. Fig. 145 is a general view of the switch employed, and will briefly be described.

Each shift of the finger increases the E.M.F. of the battery 2 volts when ascending, and *vice versâ*. The fingers are divided, and there are two supports of vulcanite fibre, each of which carries some thick wire, one coil being electrically placed between the two fingers on one side of the centre, and the other coil correspondingly attached to the fingers on the other side, the fingers on one side of the centre being insulated from those on the other side. As a result the switch fingers

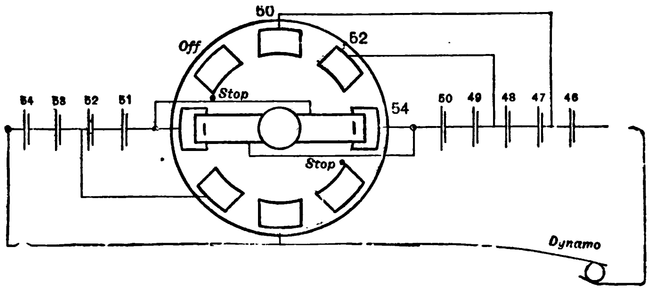


Fig. 146.—Diagram of Connections. Compound Switch.

may be moved from contact to contact without breaking the current and without burning the contacts, for the reasons just explained.

SWITCH-BOARDS.

Although switch-boards are not obligatory, yet, by their absence, confusion, frequent accidents, and often breakdowns are likely to occur. The apparatus consists simply of a board, or piece of slate, with all the requisite switches and instruments placed thereon, for the convenience of having all these together; so that the

various positions of the switch settings, currents flowing, and so forth may be seen at a glance.

Terminals for apparatus and switch-boards are made on a great variety of patterns, and the designs should be chosen according to circumstances; for there is no

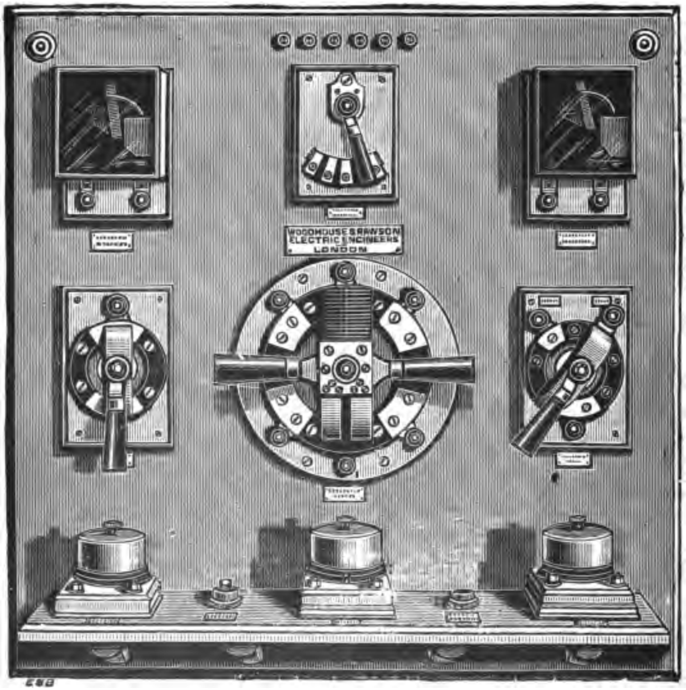


Fig. 147.—Woodhouse & Rawson Switch-Board.

one pattern which can be considered equally convenient for all purposes.

In practice, such boards are essential where smooth working is desired. Diagrams of switch-boards are shown in Figs. 147, 148, 149, and 150; but naturally

they must vary very much in appearance according to the requirements of the installation.

Fig. 148.—Drake & Gorham Switch-Board.

Fig. 147 represents a switch-board, made by Messrs. Woodhouse & Rawson, and suitable where an accumulator is used.

Fig. 148 is a switch-board, to be employed under similar conditions, on Messrs. Drake & Gorham's pattern.

Fig. 149 represents a simple double-pole switch-board, with fuses.

Fig. 150 shows a switch-board by Messrs. Nalder Bros.

Fig. 149.—Double Pole Switch-Board.

Fig. 151 illustrates a neat fuse-board made by the Acme Electric Works. There is a switch to every branch, which is found to be convenient for testing purposes, and for localising a fault. This system, to be complete, should have the switches repeated on the other main, as on the board constructed by this firm for the writer.

Fig. 152 is a switch-board by the Edison & Swan United Company.

The chief essentials to be observed in the manufacture of switch-boards are the following: the board should be of slate by preference, and should have no connections behind. All conductors out of sight should be extra

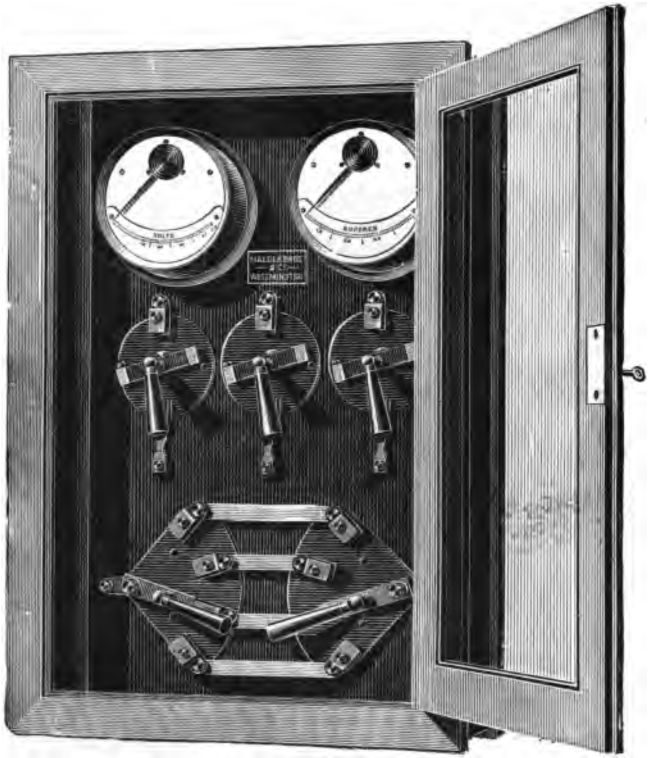


Fig. 150.—Nalder Brothers' Switch-Board.

large and of low resistance. All connections should be made on the front of the board, by means of terminals, cone pieces or otherwise. All apparatus fitted on the front should be capable of removal for cleaning

and repairs. Switches also are best mounted on slate, the cost of slate and wood being much the same.

Wood is frequently found to be a better non-conductor than slate, due to the presence in the latter of metallic particles. Besides, slate absorbs considerably more moisture than polished wood, and its conducting properties, in certain weathers and damp situations, become much impaired. On the other hand, slate has the advantage of being incombustible, and incapable of

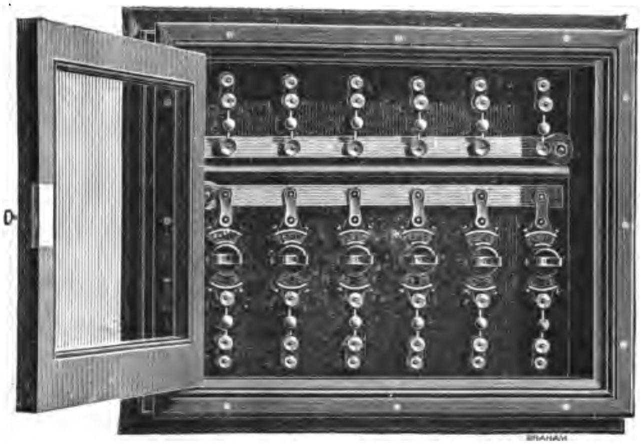


Fig. 151.—Acme Fuse-Board.

warping and shrinkage. If the following precautions are taken, the disadvantages appertaining to the use of slate may be practically eliminated. The slab should first be tested, with the view of ascertaining to what extent conduction exists. If this is *extremely* small, it may simply be due to the presence of moisture in its substance, but if there is much conduction the piece should be rejected. Having selected a piece of slate likely to

be suitable, it should be boiled in paraffin wax, so that the latter may fill all the pores of the slate. Many firms place the slate straightway into the molten substance, and as a result the slate becomes very brittle. Therefore, it is better either to warm the slate before dipping

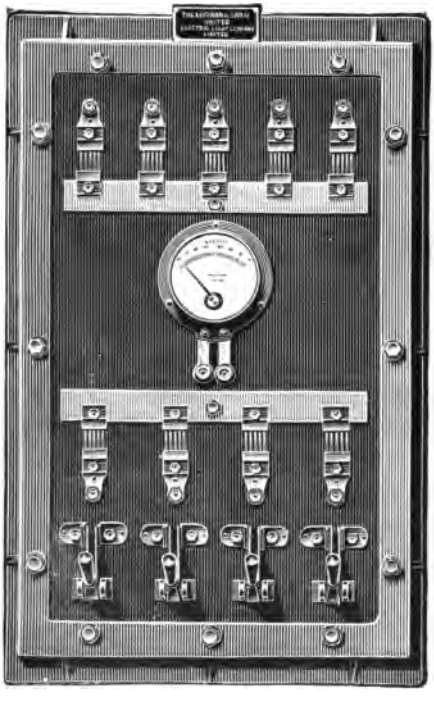


Fig. 152.—Edison & Swan Switch-Board.

it, or to place it on the paraffin wax and heat the whole together. Even with all these advantages, slate is not a sufficient non-conductor for certain classes of special work. When no leakage whatever is permissible, it is usual to cut the slate slabs and mount them upon

ebonite, so that no connection shall exist between the positive and negative sides of the switch-board, except across a certain distance of ebonite. Glazed earthenware may be used to replace the ebonite when money is an object. Slate should always be enamelled. The author has a slate switch-board mounted with ebonite in the way described, and the resistance between the positive and negative sides of the board exceeds 300,000 megohms.

All switches carrying large currents should be massive. If possible, the arrangements should be such that no settings can produce accident. All switches, cut-outs, and instruments should be fixed within easy reach. A diagram of the connections should hang alongside the switch-board for reference. In a well-designed board, the dynamo leads, the house mains and the accumulator cables need only to be brought to it, all further connections existing upon the board itself. Before making the switch-board it is desirable to think over carefully what will be the requirements of the installation, because after-alterations are troublesome, and tend to disfigure the appearance of the board. Every terminal or other part liable to be short-circuited should be protected by covers of wood, glass, or insulating material. To avoid the possibility of accident, it is best to place all switches, cut-outs, and ammeters on the same lead, positive or negative, and to colour all positive parts on the board red, for easy distinction. Two glass doors should protect all boards, each door covering one polarity. A safe practice is to put slips of vulcanite fibre between all apparatus upon a switch-board having a different polarity, such slip or slips being raised from the board to a level higher than any metal parts on the board. Thus, when

using a spanner or other tool, there will be no chance of making an accidental short-circuit.

On the mains, as well as on the supplemental switch-boards, it is a good plan to place a switch to control every branch wire which leaves the board. For testing purposes this is very convenient, and any part of a house may be cut off at pleasure for repairs, alterations, or for any other purpose.

CHAPTER VI.

FUSES, CUT-OUTS, CONNECTORS, AND MINOR APPARATUS.

FUSES and cut-outs are inserted to guard against the possibility of fire, also to prevent injury to apparatus. In some forms they are to cut a circuit out, in the event of the pressure of the current rising above a certain limit.

Fuses frequently go under the name of Safety Junctions. Opinions and experience differ greatly as to the best form to be given to these junctions. It is quite evident that, if the fuse wire is to melt for a given current, the wire will be raised to a high temperature during the time when the current is passing; for otherwise any small excess of current will not melt the fuse. It follows, therefore, that if the fuse wire is very short and the blocks to which it is attached are large, the wire will be kept cool by the heat being rapidly conducted away; and it will consequently be capable of carrying a much larger current than was intended. Hence the first point to be attended to is to see that the wire is of sufficient length, which for small currents up to, say, 3 amperes should be at least one inch. Again, it is necessary that the attachment-blocks should be of sufficient size, in order that they may not become warm. Should this, however, happen day after day, the fuse wire will

become oxidised where connected, and a bad joint will result. A bad joint heats rapidly, and a time will arrive when the fuse will melt with a current far below that which it was intended to carry. It may thus be concluded that three points are essential in connection with fusible safety junctions. (1) The wire, or fusible portion (which is sometimes foil) to be melted, should be of sufficient length. (2) The attachment blocks should not be too small. (3) A good joint should exist between the fuse and each block.

The old practice was to employ lead wire. The objection to this material is that at high temperatures it oxidises rapidly, and it is possible to heat up a lead wire fuse gradually until the metal is in a molten state, the wire still remaining intact. The reason for this is that a strong skin of oxide has formed round the wire in the shape of a tube which contains the molten metal. Tin wire oxidises far less readily, and this material is now in general use.

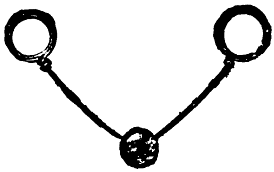


Fig. 153.—Cockburn Fuse.

Mr. Cockburn introduced a fuse (Fig. 153) of tin wire, with a small weight threaded upon it in order to break the wire at melting point. This obviates the sudden melting of the metal, which frequently splashes the attachment blocks and any apparatus near it. The method answers very well, and it is a revival of a similar system which was employed for the protection of marine cables against lightning many years before. There is very great difficulty in obtaining a good joint with tin wire. When pinched up under a screw, the metal, being comparatively soft, compresses; and unless from time to time

the screw is tightened there will be a bad connexion. A very simple way of overcoming the difficulty was brought out by the author and published in the *Electrician* of May 22, 1891, in order that the public might obtain the benefit of the method free from patent rights. It has been adopted by most makers of the present day; a proof that the plan is an advantage. Any one can make these fuses for himself. Three sizes are shown in Fig. 154.

It is only necessary to cut out a piece of copper foil with a pair of scissors to the right shape and bend a

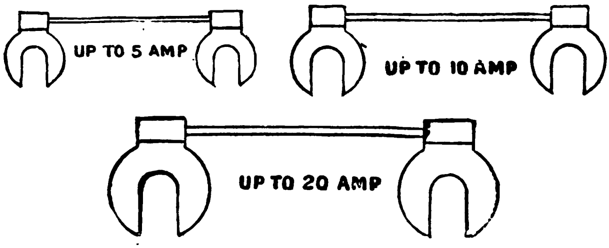


Fig. 154.—Author's Pattern Fuse.

portion round the fuse wire and pinch it up tight with a pair of pliers or in a vice. The slots in the attachment pieces form a convenient way of slipping the fuse under the screw heads without having to remove the screws themselves. By placing the finger on the copper clips the danger is obviated of stretching the fuse wire whilst turning the screw home. This is one of the greatest troubles experienced with the older system. Some makers of these fuses solder the fusible wire to the copper clips.

Another improvement introduced by the writer is that of placing under the fuse binding-screw a washer

carrying a steady pin, which passes loose into the fuse block. This little addition entirely gets rid of any tendency on the part of the fuse to twist round on turning the screw home.

When it happens that the attachment blocks are very close together, then, in order to insert a longer fuse, the wire may be allowed to form a festoon. It is of the greatest importance that all fuses should be enclosed in incombustible cases. Many accidents have occurred for want of attention to this precaution. The covers should be easily removable, and the method of replacing a fuse should be convenient and capable of being done without the use of tools. As far as possible, all fuses should be placed at accessible points within reach.

The mains and branches are always laid to carry safely for any length of time at least twice the current required, and, under these conditions, ten times the maximum permissible current may be passed for a short period without risk. Hence there is no necessity for these safety devices to cut the circuit for any special current, so long as the setting is kept well within allowable margins; for instance, say three times the current intended to be used for that particular main or branch.

Fusible junctions are mostly in use. They consist of wire or tin-foil, which melt on too much current passing, the section of the material being adjusted to the requirements of the circuit. Mr. Alexander Siemens and others have shown that no danger to insulation occurs until a temperature of 150° C. is reached; also that no fusible junction should be employed which will melt till three times the current is passed which it has to guard. If the fuse goes at a less margin, it gradually oxidises,

and, eventually, the circuit is cut when not intended and great inconvenience may result. We see that the 200 per cent. margin provides really more than ample safety.

Mr. Preece advocates the use of platinum wire for fuses, as this metal does not oxidise in the air. He has shown that, for any current which renders a platinum wire red hot, double that current makes it white hot, and three times the current which makes it red, fuses it. This is interesting from a scientific point of view, but the possibility of having a number of white-hot fuses about a house is not to be courted. For very heavy currents copper wire is sometimes employed.

The author's experience is, that for fusible cut-outs, ordinary tin-wire answers quite as well as any of the numerous types of fuses which have been brought into the market, and, combined with Cockburn's improvements, there is nothing more to be desired.

From the remarks already made it is evident that to have a fuse so accurately adjusted as to protect a lamp is likely to cause its extinction at almost any moment, since the margin allowable is so very small.

It is unquestionably better to rely upon the good design and workmanship of the installation for the protection of the building than upon devices which are intended to come into operation only in cases of carelessness and accident. If cut-outs are used with this view only, the security sought is completely obtained.

When many fuses are placed upon one board it is important so to arrange matters that, if any one fuse melts, the molten metal shall fall clear of all apparatus upon the board.

Besides the fuses just described, many other designs have been brought out for cutting the circuit, depending upon a rise in temperature, such as the well-known cut-out consisting of two different metals soldered to-

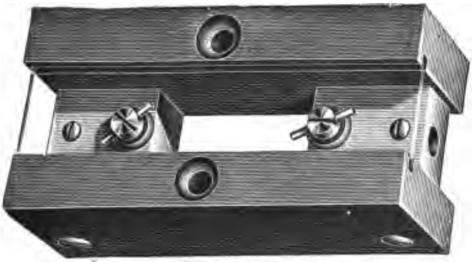


Fig. 155.—Single Fuse Block.

gether, and working by expansion and contraction; also another made with mercury. But these need not now be discussed, for common safety junctions acting by fusion

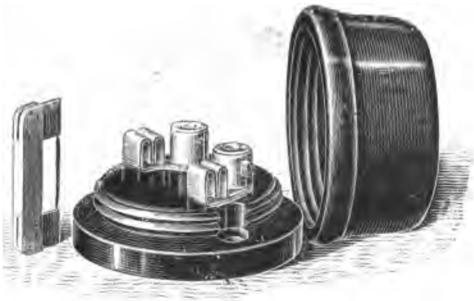


Fig. 156.—Drake & Gorham Fuse.

are far simpler in construction and more reliable. Magnetic cut-outs are, however, an exception; and a large variety of these exists. They can be arranged to go off for a definite current.

The following are a few examples of safety junctions :—

Fig. 155 is a Drake & Gorham's fuse block, which is

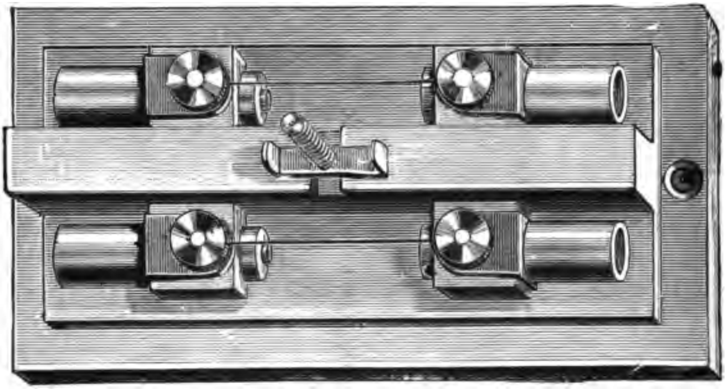


Fig. 157.—Exchange Type.

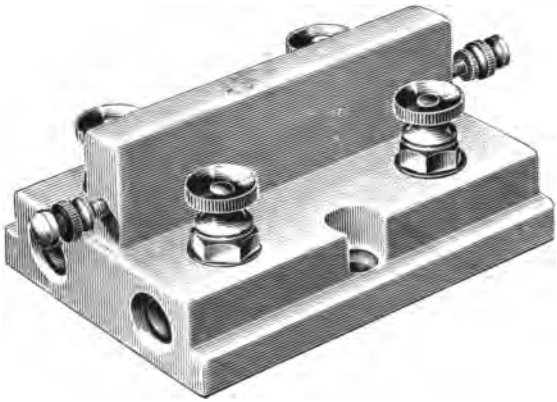


Fig. 158.—Champion Type.

made of porcelain, a piece of glass being slipped over as a cover.

Fig. 156 is Messrs. Drake & Gorham's pattern.

The fuse in this instance is something like a fiddle-bow. The bow portion is made of vulcanite fibre, the

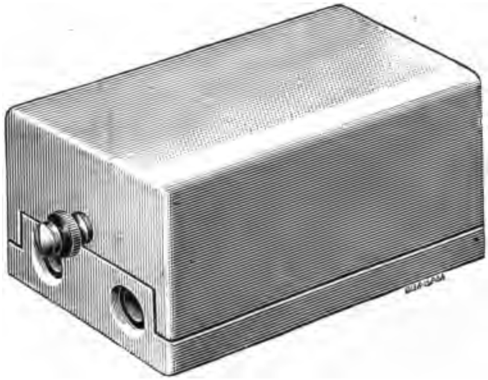


Fig. 159.—Champion Type.

Fig. 160.—Spring Fuse Block.

fuse wire taking the place of the string and attached to little copper plates at each end, and the fuse is forced in between springs.

Fig. 157 is sold under the name of the "Exchange

Type." It illustrates a double-pole fuse on one porcelain block with the cover off. The leads in this type are soldered into the sockets shown at the ends.

Fig. 158 is the "Champion Type," with the cover removed.

Fig. 159 shows the fuse block, with the cover in place.

The last two are supplied by the General Electric Company.

Fig. 160 illustrates another pattern sold by Messrs.

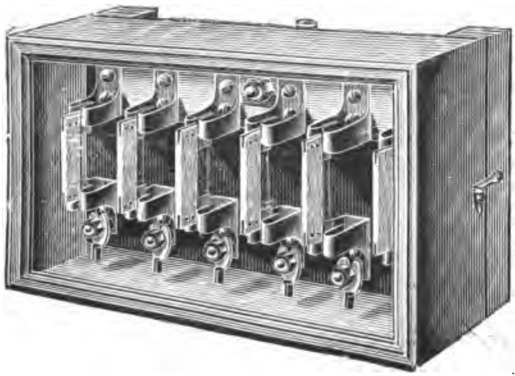


Fig. 161.—Multiple Fuse Board.

Woodhouse & Rawson. The fuse wire is in a glass tube, and is held in place by springs.

Fig. 161 shows a number of fuses upon one board, as made by the Edison & Swan United Company. The fuses are sprung in place.

Fig. 162 is a compound Cockburn fuse intended to carry about 100 amperes. Each fuse wire is made to melt for about 25 amperes.

In the Edison fuse a socket is used, into which a plug containing the fuse wire is screwed. For many

purposes this is a convenient fuse. When a new one is required it is only necessary to unscrew the plug and throw it aside, and to insert a new one.

A double-pole Edison fuse is shown in Fig. 163, and a single-pole fuse in Fig. 164. The plug containing the fusible wire is illustrated in Fig. 165.

Fig. 166 is a fuse intended to be used with high-tension currents, Ferranti's pattern.

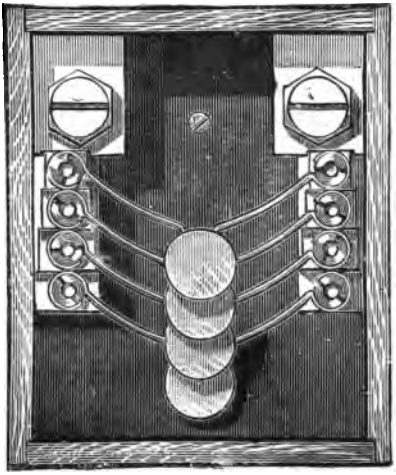


Fig. 162.—Compound Cockburn Fuse.

Fig. 163.—Edison D. P. Fuse.

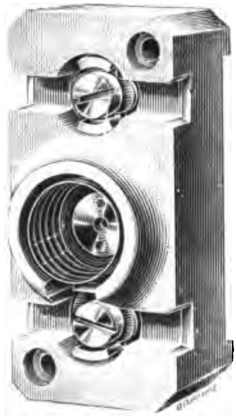


Fig. 164.—Edison Single Fuse.

The fusible wire is attached to two plugs having ebonite handles, so that it can be inserted without danger to life.

Recently a new form of high-tension fuse has been introduced by Mr. Bates, and it is likely to supersede all others. The fuse wire is placed inside a small tube, and at the moment of its melting a strong puff issues from each end of the tube and puts out the spark. It is probable, therefore, that the present use of long fuses with high-tension currents will soon be discontinued.

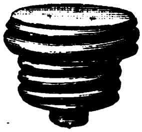


Fig. 165.—Edison Fuse Plug.

To turn to the magnetic class of cut-outs, Cunynghame's magnetic tumbler cut-out is by far the best of all present patterns. A diagram of this is shown in Fig. 167. The current passes through mercury, but this is not an objection. When the current becomes too large, the magnet draws up the armature, with the arms which

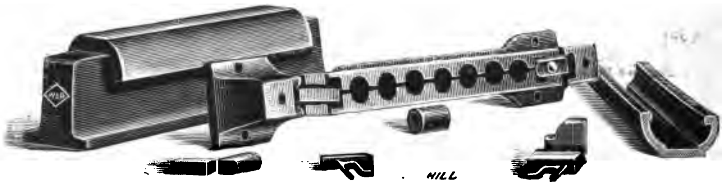


Fig. 166.—Ferranti High Tension Main Cut-outs.

dip in the mercury cups, to which they are attached; and the circuit is cut, not to be re-established except by hand, since the momentum given to the moving armature causes it to pass over the magnet and to fall against a pin on the opposite side to that where the mercury cups are; and the magnet loses its power the moment the arms are withdrawn from the mercury, since

it is excited by the main circuit, for the insulated copper wire or ribbon wound around its core forms an integral portion of the main, which passes to one mercury cup and continues from the other, the break being bridged electrically by means of the arms when they rest in the cups. These devices are exceedingly useful where cut-outs are likely to go often, such as those employed with motors, in the engine-house, and for experimental work, since they can be reset at once; for a fuse takes longer and is more troublesome to replace. For use on board ship the instrument is somewhat modified in construction.

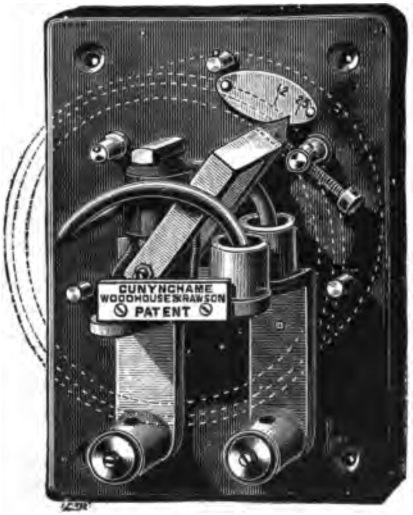


Fig. 167.—Cunynghame Cut-out.

Magnetic cut-outs can be constructed for alternate currents, although those illustrated are intended only for direct currents.

Fig. 168 illustrates a modified form of Cunynghame's cut-out, also made by Messrs. Woodhouse & Rawson.

In this case the magnet or core is an arc of a circle, and its winding is a stiff wire, which can move about a pivot with the core in its axis. The details are clearly shown in the figure. The setting is effected by putting more or less core into the solenoid.

Mr. Cunynghame has also introduced another form of magnetic cut-out, which he terms the "Hammer." The object aimed at in this apparatus is to obtain instantaneous action. This is brought about by discharging a weight, which by its fall actuates the apparatus that cuts the circuit.

Fig. 169 is a magnetic cut-out supplied by the General Electric Company, but it has no advantages over those described.

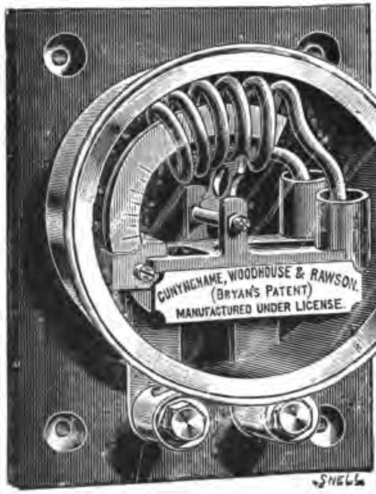


Fig. 168.—Cunynghame Cut-out. (Another form.)

There are other forms of cut-outs which must not be omitted. One is for protection against lightning, and the other is to break the circuit in the event of the pressure of the current rising too high in a house. There is an endless number of devices for effecting these two objects, but only one of each need be indicated.

Fig. 170 is a simple form of lightning guard, wherein

the two outer half-circles of metal are connected, one to the positive and one to the negative main, with a fuse inserted in each case. The circular central block of metal is "earthed." If the wires should be struck by lightning, the spark will jump across the space between the blocks of metal to earth. The base, of course, is made of some incombustible non-conductor.

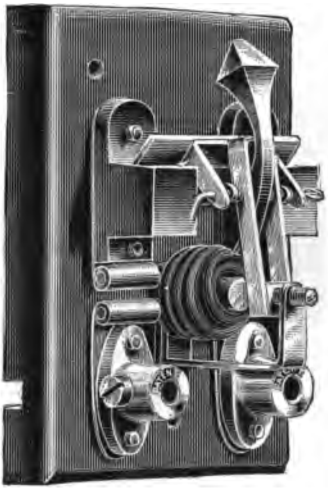


Fig. 169.—Magnetic Cut-out.

For the protection of a circuit against high pressure Cardew's Safety Device has been largely used. It is shown in Fig. 171 with the cover on, and in Fig. 172 with the cover off.

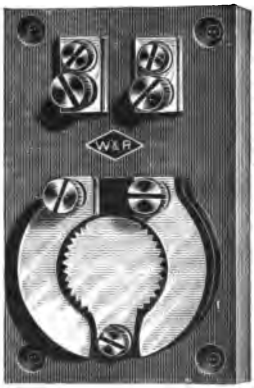


Fig. 170.—Lightning Guard.

The device consists of two insulated metal plates, one in connection with a house lead and the other with earth. Between the two there is an aluminium foil, attached to neither plate, and resting upon the lower or earth plate. If the E.M.F. rises above 400 volts, one end of the foil is drawn up and brought into contact with the plate in connection with the house main, which is consequently earthed. If, there-

fore, the voltage should rise too high, the main fuse ought to melt. In the case of direct current circuits it is clear that such a device ought to be placed on each main to ensure perfect safety, although one suffices for alternate current circuits, always provided that it acts when required.

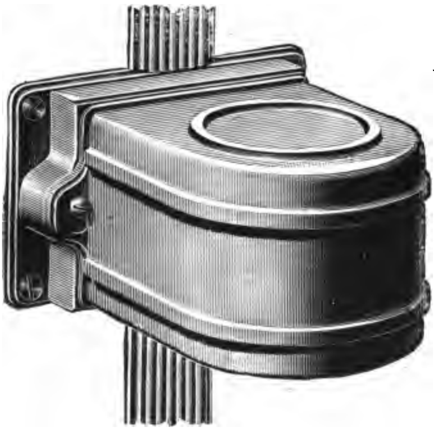


Fig. 171.—Cardew's Safety Device, with Cover on.

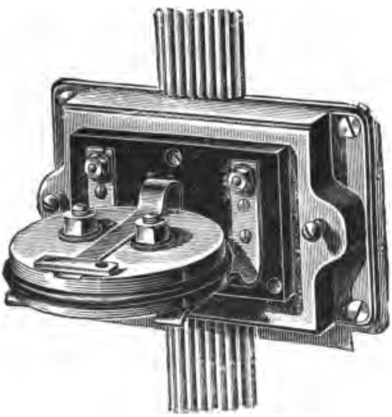


Fig. 172.—Cardew's Safety Device, with Cover off.

The next fittings to claim consideration are those for connecting all pieces of apparatus with the circuit. These may be comprised under three heads, viz. (1) Terminals, (2) Wall-connectors, and (3) Ceiling-roses. Little need be said in regard to terminals, as they are so familiar to all; but there is one point which should be attended to when these are

used. The positive or negative terminal, or both, should be protected by a cover to prevent the chance of making an accidental short circuit.

Wall-connectors are made in a vast number of ways, but the following are the essential points for a perfect piece of apparatus. The whole connector, excepting the portions which carry the current, should be fireproof and a non-conductor. Porcelain is probably the best material, but being breakable it should be encased in metal and this covering should be screwed to the wall, and not the porcelain parts, as in many wall-connectors that are sold. If these points are attended to, numerous accidents, due to the connector receiving a blow or arising from the weight of some heavy attachment, will be avoided. The wall-connector should contain a fuse in a convenient position and not less than 1 inch in length. The terminals for the fuse should be substantial, and whatever system may be employed in the connector for attaching the portable or other apparatus to the circuit should be of such a nature that thoroughly good contact is established. The contact pieces in the connector should be so placed as to render it very difficult for any adult or child to make a short circuit either accidentally or intentionally. Many an accident has occurred through the children playing, for instance, with hairpins. The contact pieces in the connector should be within it and not of the nature of pins, or any other projections, sticking up from its surface. The form given to the face of the connector should be such as to render it easy for the plug to be inserted. All screws should be hidden when the metal case is screwed on, every part should be accessible, and the fuse be capable of replacement without the use of tools.

A number of examples of wall-connectors will be given. The majority of these are very convenient in practice, but most of them are to be condemned because of the omission of some one or more of the points just mentioned.

The author was anxious to place a wall-connector in his installations as safe and as convenient as it was possible to make this apparatus. His design has been carried out and the connector is quite successful and meets all the conditions indicated above; together with another advantage, that of being able to use it as a wall-bracket and as a ceiling-rose besides. For this reason it has been called the "Universal." The heaviest electrolier may be suspended with this connector without danger, since no weight is taken by its porcelain parts. The only disadvantage is the expense of its construction. The apparatus is very simple, but being thoroughly well made throughout it cannot be ranked with the cheap wall-connectors in general demand. The outer case is of solid metal, and the porcelain base, which carries the electrical portions, is so arranged as to be free within the casting. When this connector is used as a ceiling-plate, or for a standard, the weight of any fitting is completely carried by the metal portions; so that no strain is placed upon the porcelain. It is taken apart by unscrewing the cover, which has a flange that covers the screws fixing the whole apparatus to the wall, floor, ceiling, or table. The back of the metal base plate has a ring of vulcanite attached, to avoid the possibility of creating a short circuit if the wires pass too close to the metal. Before the metal cover is screwed over the base plate, a porcelain loose cap is put over the electrical portions, so that these are entirely encased by

non-conducting and incombustible material. It contains a fuse one inch long, in accordance with fire-risk regulations. The front end of the metal cover has a thread around it to receive an ornamental ring. This ring is made in a number of ways according to the purpose for which the connector is to be used. When employed as a ceiling—or bracket—plate the connector-plug is covered by a cap so made that the ring holds it firmly in position, thus preventing the possibility of the plug being drawn out by the weight of the lamp-fitting. This method also applies when the connector is used as a standard fixed on a table, desk, or the floor, unless it be desired to have the fitting removable without the necessity of unscrewing the ring.

Messrs. Faraday have carried out this wall-connector in a very admirable way, which is no small point in the success of any piece of apparatus. The plug to be used with this connector is of the two-pin type. The contacts within the connector are spring tubes, into which the pins push.

The two-pin principle was first introduced by that able and ingenious designer, Mr. Taylor-Smith, whose designs are daily being supplied to the public under the names of various makers who are in no way entitled to the credit of their origin. The face of the wall-connector has a groove, which enables the holes for the pins to push into to be readily found. An improvement has also been introduced into the plug, and has now been largely copied. Till recently, in order to connect the wires to the pins in the plug, it has been customary to remove a piece of wood or vulcanite fibre at the back by undoing two screws with a screw-driver. The pins themselves were screwed into the wooden

block. The result of this method of construction rendered it troublesome to make the connections, and the pins became loose in a very short time. The method introduced by the writer is so simple that it seems extraordinary it had not been adopted earlier. The piece of wood forming the back of the plug, instead of being screwed in with two screws, has its periphery threaded, so that what was formerly the plug itself is now the cover, and screws on the base piece like the lid of a box. The pins are fixed to the wooden disc by means of a nut on each side of the pin, these nuts pinching the wood between them. It is, therefore, impossible for the pins ever to become loose. All connections are made in the "open," instead of being done, as formerly, in the bottom of a small box. This arrangement also offers the facility of adding a third nut-and-screw on the base, thus rendering it possible to insert a small fuse in the plug; which, in nine cases out of ten, is a matter of great convenience, for if this fuse is arranged to melt for a slightly less current than that in the connector, the portable, or removable, portion only has to be re-fused; an operation more easy to perform as a rule than re-fusing the connector, which is frequently fixed in an inconvenient position. The idea of fusing the plug is probably due to Mr. Massey, but the usual construction of this piece of apparatus precludes the possibility of carrying out the suggestion.

In the case of the author's wall-connector and plug, the details for conversion into a ceiling-connector, or the fittings, are here described. For the sake of appearance the plug is covered with an ornamental metal cap, which for pendants and wall-brackets is of practical service. The edge of the cap is spun out, and a

ring which exists on all the wall-connectors is removed. The plug is now inserted and the ring screwed on, which takes the spread-out portion of the cap, so that the plug can no longer be pulled out. In this way a ceiling-rose or connector is formed for suspending a lamp by means of a twin wire. If a metal fitting or wall-bracket is to be employed, then a boss is riveted to the face of the cap and into it the fitting is screwed. Obviously, therefore, the whole of the fitting is carried directly by the metal-work of the connector, and no strain whatever is put upon the porcelain parts of any of the wires in connection with it. When a house is shut up, or is being cleaned or decorated, every fitting can be removed at a moment's notice. All that is necessary in any case is to unscrew the ring and pull a fitting out.

Fig. 173.—Central Pin Connector.

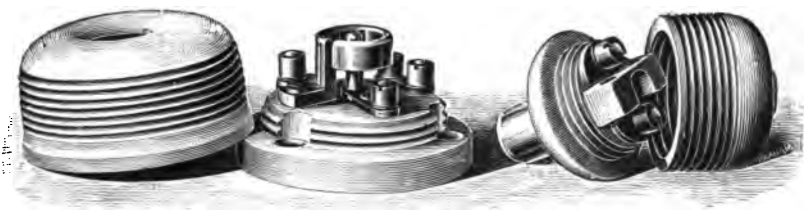


Fig. 174.—Central Pin Connector.

The following are a few illustrations of wall-connectors and plugs in use at the present time.

Fig. 173 shows the plug inserted into the connector,

and Fig. 174 shows the apparatus taken apart; and both portions are made of porcelain, and supplied by the

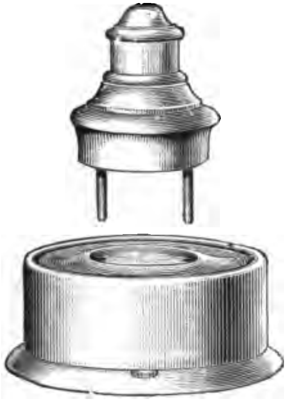


Fig. 175.—Pin Connector.

Fig. 176.—Pin Connector.

Fig. 177.—Central Pin Connector.

General Electric Company. In this connector the connections consist of a central split pin and a concentric split ring. The plug has two concentric tubes insulated from one another, one fitting over the pin and the other inside the ring. The chief disadvantage of this connector is that any piece of metal being inserted between the central pin and the ring will create a short circuit.

Figs. 175 and 176 show two forms of connector as supplied by Messrs. Woodhouse & Rawson.

The following also are supplied by the same firm

and indicated in Figs. 177 and 178. The latter of these is, in principle, similar to the plug illustrated in Fig. 174, but safer in use.

Fig. 179 represents a wall-connector and switch combined. The plug is inserted and turned to put the current on.

Fig. 178.—Pin Connector.

It is frequently convenient to be able to attach a portable lamp, or other piece of apparatus, to a lamp socket, which then becomes a connector. Fig. 180 shows a plug in porcelain which fulfils this requirement.

Fig. 179.– Wall-Connector and Switch Combined.

Fig. 181 is a wooden adapter for a similar purpose, and this one is made by the Edison & Swan United Company.

There are many other designs of plugs and connectors,

all of them more or less on these principles. Several exist wherein to pull out the plug a quarter or half a turn must be given, the intention being that these plugs shall be used for ceiling-roses, for easy removal of the fitting. Very few made on this principle are of a good pattern. Besides the one figured there are other wall-connectors which act as a switch by giving the plug a twist to the right or left, thus turning the current on or off. The author prefers an independent switch for every connector. The chief difference between a wall-connector and a ceiling-rose, or ceiling-plate as it is sometimes called, is that for the wall the fitting is usually a portable one and requires to be removed, whereas a ceiling fitting is a fixture. The pendant or electrolier is attached direct to the ceiling-plate. There are in use a large number of patterns, but as they are all very similar, except in details, one example will suffice.

Fig. 180.—Plug for Lamp Socket.

Fig. 181.—Plug for Lamp Socket.

Fig. 182 illustrates a ceiling-rose with a cover on ; Fig. 183 with the cover off.

It will be noticed that each wire going to the fitting is attached to a metal plate on the base. The third metal plate is to enable a fuse to be taken from it to one of the others. The leads to the lamp pass through the central tube.

A piece of apparatus of great importance, though

insignificant in itself, is the lamp-holder. In almost every instance of domestic lighting glow lamps are used, arc

Fig. 182. – Ceiling-rose.

Fig. 183.—Ceiling-rose, with Cover off.

lamps not being suitable for lighting houses. There are several ways in which a glow lamp may be connected to

the circuit, but in all cases a lamp-holder is connected to the circuit first, and to the former the lamp is attached. The chief forms employed for attaching a lamp to its holder are, by means of platinum loops, "bottom collars" (written shortly B.C.), to fit the bayonet socket

Fig. 184.—Loop Lamp-holder.

Fig. 185.—Loop Lamp-holder.

and the Edison fitting, where the lamp is screwed into its holder. There are besides many other ways, such as the central fitting, the side loops, &c. The simplest form is that of the loops or bottom loops. The holders for these lamps all consist of two parts: two little hooks which are connected with the leads, and which pass

through the loops of the lamp, and some form of spring to produce a tension by pushing the globe of the lamp away from the fitting, whereby the loops and the hooks form a good connection.

All the fittings illustrated are made by the Edison & Swan United Company, but other firms also make many of them under license.

Fig. 184 shows one of the simplest forms. It is for screwing into a fitting.

Fig. 185, the same for a pendant.

Fig. 186 is a loop-holder with a different form of spring.

The bayonet socket-holder is shown in Fig. 187. It is intended to screw on a fitting.

Fig. 188 illustrates the interior portion in two positions. The base is made of an incombustible non-conductor. The upright pins are spring pistons. The manner in which this holder is put together is shown in Fig. 189.

Fig. 186.—Loop Lamp-holder.

One of the spring pins is here seen in section. It will be noticed that there is a piece of metal threaded to screw on the fitting. Into this is dropped the base carrying the spring pins. Over this is put a tube, in which the bayonet slots are cut; a ring passing over this screws the whole together. The tube has a projecting tooth upon it (not seen in the diagram), and which fits into the other metal portion, in order that,

when putting on the ring, no other part of the fitting may turn. The little funnel-shaped hole, with a screw passing into it, is the place where one of the wires is attached from the circuit and in connection with one of the spring pins. The other wire is attached in the same way to the second pin. The socket end of the lamp to fit into this holder is cylindrical in shape, and consists of a brass ring with two projecting pins which turn into the

Fig. 187.

Lamp Socket.
Fig. 188.

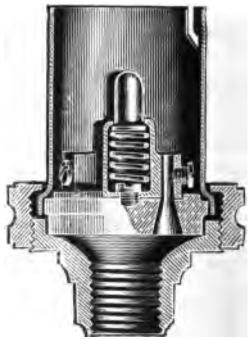


Fig. 189.

bayonet slots. In doing this the springs become slightly compressed, and the socket is prevented from turning round by reason of a small portion of the metal being removed at the end of the slot, as seen in Fig. 187. This ring is filled with plaster of Paris, in the centre of which will be observed two little brass plates. These are connected to the ends of the filament by means of platinum wires. These plates press upon the pins.

To convert this holder for use as a pendant the fitting,

the piece shown in Fig. 190, is screwed into it. It contains a piece of wood in the shape of a fishing-float cut in half longitudinally, as seen in the figure, where the wood projects and two grooves are cut which clamp the wires when the metal cap is screwed up.

Fig. 190.—Cord Holder.

This is a very convenient accessory for pinching the wires, thus avoiding the tying of a knot in them, which is so common a practice.

The holder shown in Fig. 187, when it is intended to carry a shade, has an additional ring screwed upon it, as illustrated in Fig. 191.

Fig. 191.—Lamp Socket with Shade Ring.

Fig. 192.—Loop Adapter.

In order to adapt a loop lamp to a bayonet fitting, the adapter (Fig. 192) is supplied.

Fig. 193 is an Edison holder, which comprises a screw

insulated from the outside case and a disc of metal situated centrally at the bottom. One lead is connected to this disc and one to the screw.

Fig. 194 shows an adapter for a loop lamp to be used with this holder.

Fig. 195 represents a bayonet socket, with a self-contained switch.

For lamps of high candle-power a better connection is required, and the attachments usually consist of small

Fig. 193.—Edison Holder.

Fig. 194.—Edison Loop Adapter.

copper plates. This method is employed for 100 c.-p. lamps and above. A 100 c.-p. lamp-holder is shown in Fig. 196.

It will be observed that the copper plates on the lamp are held tight in the two little vices, seen in the figure. The three metal prongs are for carrying a shade.

It is not an uncommon practice to use imitation candles for portable lamps, and upon brackets, &c., the lamp in each case being put in at the end of an imitation candle. A great number of devices exist to accomplish this end. It will suffice to show one. This is seen in Fig. 197.

It will be noticed in this instance that the lamp is screwed into its holder.

A few words on glow lamps will not be out of place in this chapter.

Fig. 195.—Holder with Switch.

The Incandescent lamps used at the present day almost universally are those made by the Edison & Swan United Electric Company. They consist of an exhausted glass globe containing a very fine filament of compact carbon, which has a very high resistance. The ends of this filament are brought, electrically, at a short distance apart, to the outside of the globe, by being cemented to two platinum wires which pass through the glass, where they end in loops or some other suitable attachment for connecting to the lamp-holders which are joined to the conductors. As

yet platinum appears to be the only metal that can be satisfactorily sealed in glass, and does not permit of air following its course, thereby destroying the vacuum. When a metal is heated, its resistance becomes greater; but, with carbon, when it is raised to a higher temperature, its resistance becomes less. Consequently, the amount of current which a lamp will take in practice cannot be calculated by measuring the resistance of the filament when the latter is cold. When the filament is heated it passes through the usual stages of dull red heat to white hot; and if further heated, the distinct outline of the filament is no longer seen. At this point, the filament is said to be in a state of irradiation, and this is its proper incandescing point; if further heated, a faint violet light fills the interior of the globe, due possibly to gases (probably H gas) being given up from the

Fig. 196.—Lamp-holder.

platinum, and finally the filament breaks. The length and section of the filament determine its light-giving power, and lamps which require 30 watts for 8 c.-p. are supposed to last at least 2,000 hours if a higher E.M.F. is not employed than that for which they were intended.

Fig. 197.—Candle Holder Socket.

It is generally well known that the filament in these lamps universally consists of carbon. Many experiments have been made to employ other material, but carbon has always held its own. The manner in which the filament is made may be briefly stated as follows. A celluloid thread is bent to the required shape and then carbonised, the ends are cemented to short pieces of platinum wire, and these pieces of wire are to pass through the glass globe for making the outside connections. The filament is placed in one end of a bulb of glass, in which it is enclosed with a blow-pipe. The other end of the bulb is attached to a mercurial air-pump, the globe is then exhausted and the filament "flashed" by bringing it into a state of incandescence, by the passage of an electric current, in the presence of coal gas which is let into the bulb after the removal of the air; this flashing process being employed to render the filament non-porous. The bulb is then exhausted and sealed. The resistance of the fila-

ment determines, for a definite current pressure, the amount of current which will pass through it; and, consequently, the section given to the filament must be suitable to carry the current.

The amount of energy required to incandesce the lamp determines its candle-power efficiency. When the white heat stage is reached, the filament no longer appears as a fine line to the eye; and this is the normal incandescence of the lamp.

One hundred volts may be regarded as the standard pressure for use on an electric-light circuit. The public supply companies have adopted this pressure, and for many reasons it has great advantages.

If a lamp is to be exceedingly economical, its life will be comparatively short. Should the voltage employed with a lamp be somewhat higher than that for which it was intended, its life will be shortened; but its efficiency, as regards the amount of light given for a definite cost, is improved. Therefore, it must rest with the user to decide whether he would rather have more light, and change his lamps more frequently for a given sum; or take less light, and change his lamps less often, paying more in consequence. Nine persons out of ten would choose the former course, without giving any further thought to the matter; but it may be pointed out that the adoption of the latter alternative is to householders decidedly preferable, for two reasons. (1) It is generally inconvenient to replace the lamps, steps or ladders being required for the purpose; and these apparatus are rarely moved about a house without doing some mischief. (2) When a glow lamp is incandesced very high, the light given is painfully bright and exceedingly injurious to the eyes.

An idea of the amount of current that various lamps take when the current has a pressure of 100 volts, will appear from the following figures :—

8 c.-p., 0.3 to 0.35 ampere ;
16 c.-p., 0.6 to 0.7 ampere ;

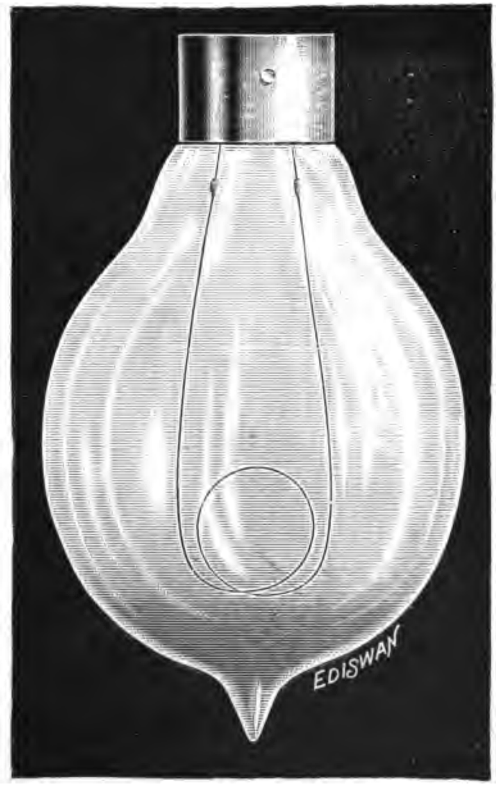


Fig. 198.—B. C. Lamp.

and so on in proportion, the light given by a glow lamp being proportional to the amount of current passing

through the filament. But a lamp made to pass a given current cannot be used for an appreciably larger current, or it will be destroyed.

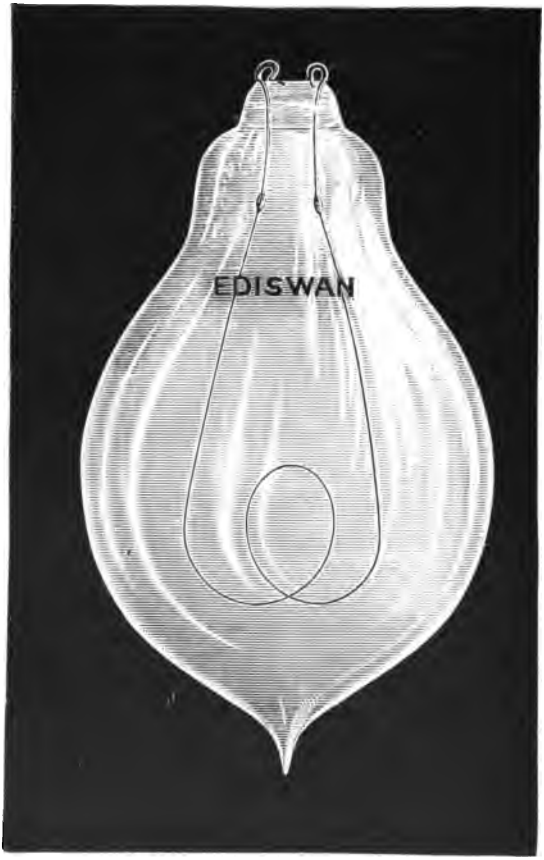


Fig. 199.—Loop Lamp.

The following are a few examples of the lamps as at present made by the Edison & Swan Company,

whose monopoly terminated in November of last year, 1893:—

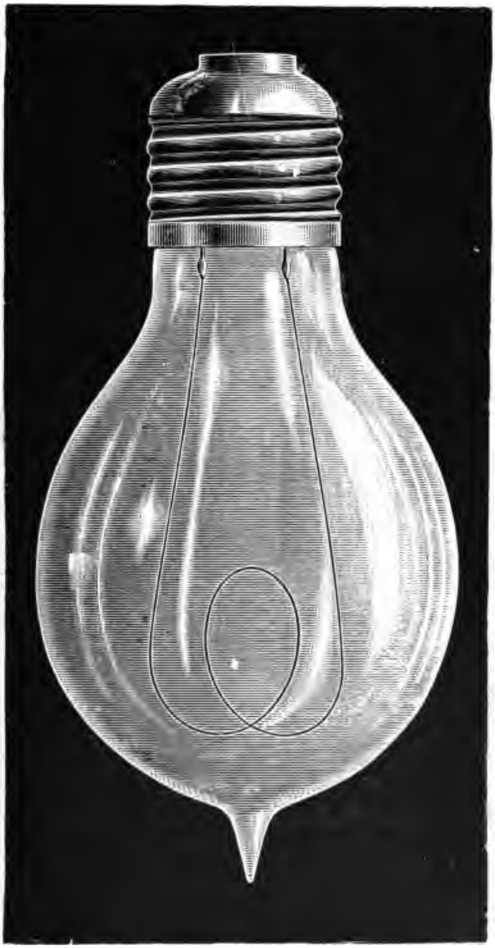


Fig. 200.—Edison Socket Lamp.

Fig. 198 illustrates a bottom-collar lamp, for the bayonet socket.

Fig. 199 is a loop lamp.

Fig. 200, a lamp with an Edison screw-socket.

Fig. 201 represents an ornamental form of lamp simulating a candle flame.

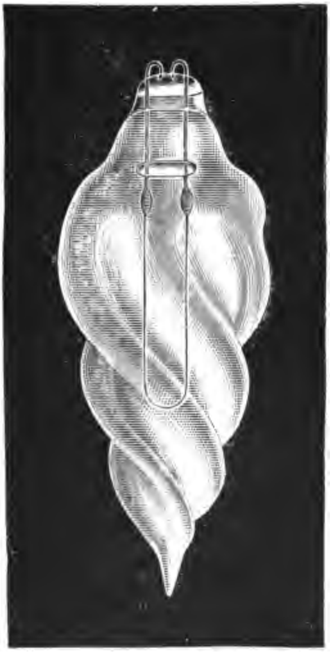


Fig. 201.—Ornamental Lamp.

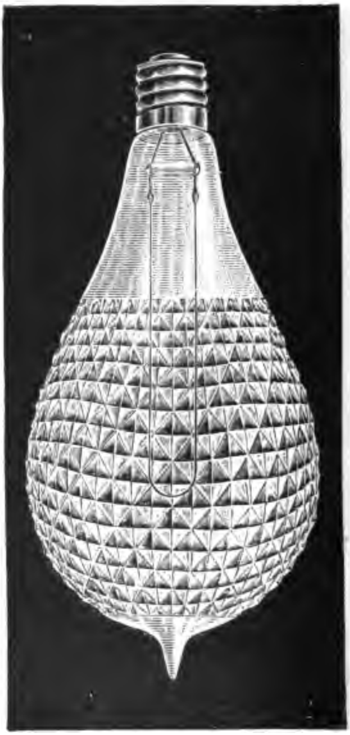


Fig. 202.—Ornamental Lamp.

Fig. 202 shows an ornamental lamp, with the globe moulded to imitate cut-glass.

Fig. 203 is a lamp intended for train-lighting. It has two filaments, the small one being incandesced during

the time the train is standing, and the longer one when the train is running; because, with some systems of

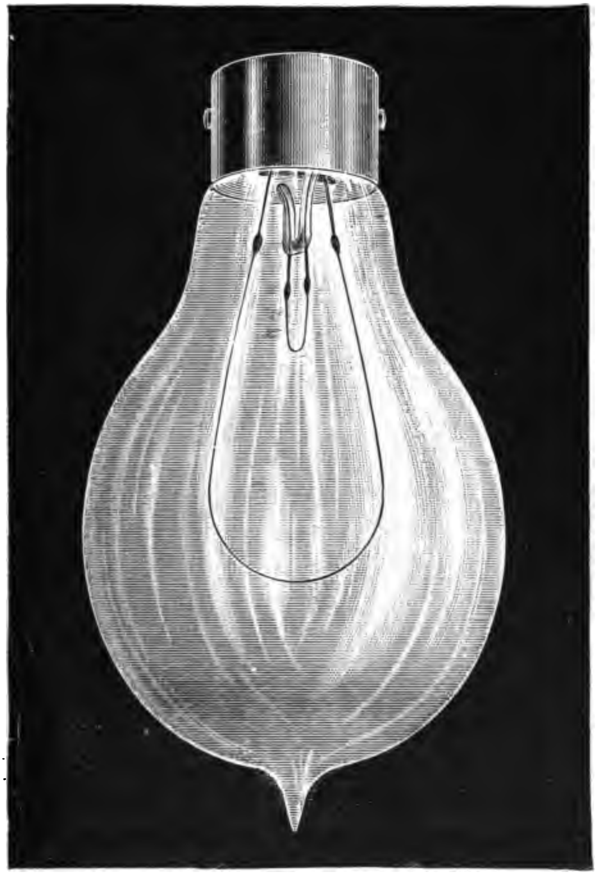


Fig. 203.—Two-filament Lamp.

train-lighting, a dynamo, during the time that the locomotive is in motion, is charging a small accumulator, and

the E.M.F. is higher while the train is running than when standing.

Some lamps are made with two filaments of equal length, for signalling and other purposes; so that, in the event of one filament breaking, the other shall immediately come into action. The lamps which now compete with the Edison & Swan productions are almost exact copies of their wares.

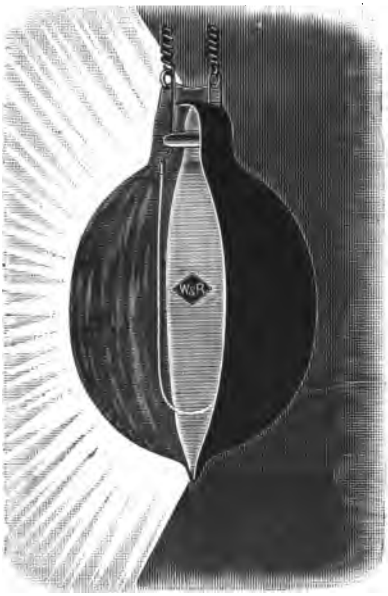


Fig. 204.—Silvered Lamp.

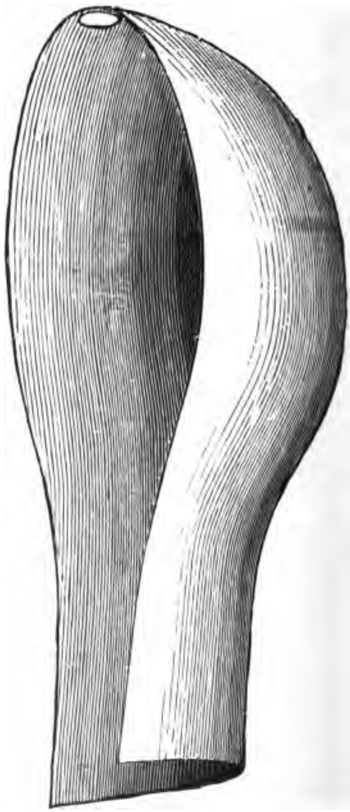


Fig. 205.—Reflector.

Fig. 204 illustrates a lamp with one half silvered, the filament being well within the focus of the curvature of

the globe, so that the rays are reflected divergently. Such lamps, or their equivalent, *i.e.* lamps with reflectors placed close behind them, are largely used where illumination is required to be given from one side only. The light in this manner is almost doubled.

Fig. 205 represents a reflector, which fits close upon the lamp.

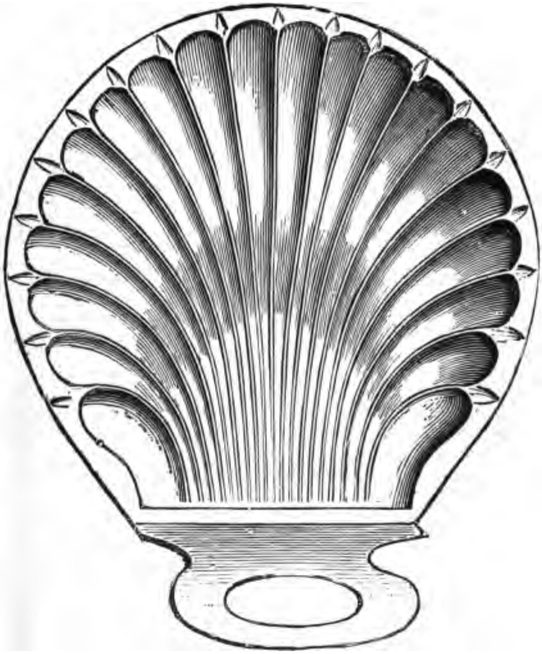


Fig. 206.—Shell Reflector.

Fig. 206 is an ornamental shell frequently used as a picture-reflector. The above two reflectors can also be obtained in porcelain.

Fig. 207 shows a lamp suitable for use in a magic lantern.

The lantern must be very large, on account of the great heat which is produced from high-candle-power incandescent lamps.

Fig. 208 illustrates the front and the side view of a special lamp, intended for illuminating the stage of a microscope, and for other purposes.

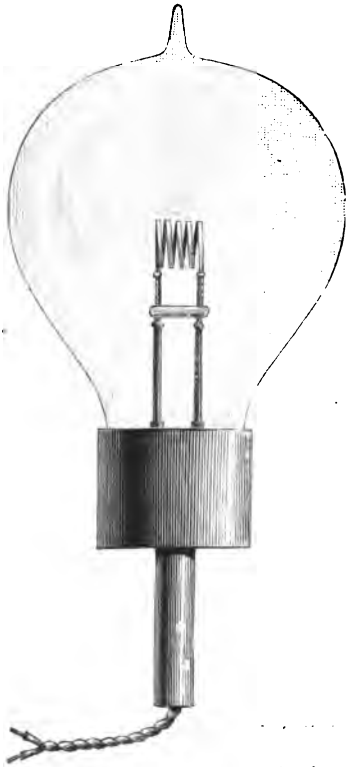


Fig. 207.—Focus Lamp.

The lamp, Fig. 209, is adapted for the same purpose, but of a different construction. Fig. 210 is a holder suitable for the lamp shown in Fig. 207.

Fig. 211 is a lamp for doctors and dentists. It is carried upon a handle not unlike a penholder; and it can be placed in a wound, or inside the mouth, for examination purposes.

All lamps may be frosted, or made of coloured glass, or decorated in any way that is desired.

In installation work it is no uncommon requirement to connect with a circuit a piece of apparatus which is intended to be used with a current of lower pressure than that generally employed; also for regulating the speed of motors; for lowering the light

given by lamps in the way that it is done on the stage ; and for a variety of other purposes. In order to accom-

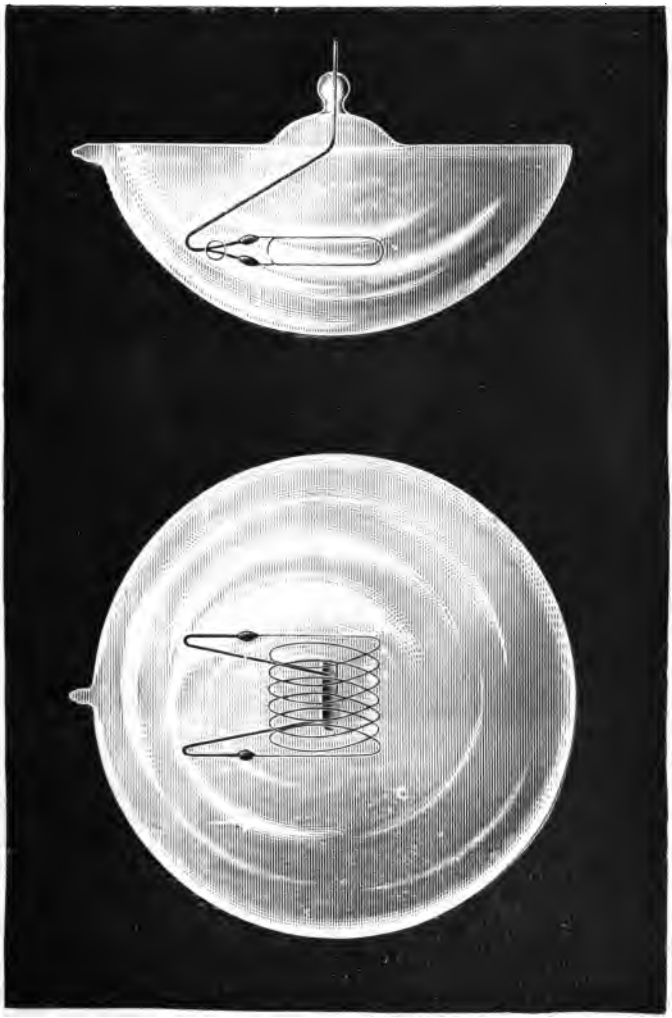


Fig. 208.—Special Focus Lamp.

plish this end with a direct current, either counter E.M.F. cells must be employed, or artificial resistances. As a rule the former are inconvenient.

The following diagrams illustrate a few forms of resistances :—

Figs. 212, 213, and 214 show three very ordinary forms of resistance frames; and on two of them, it will be observed, there is a regulating switch. In the case

Fig. 209.—Focus Lamp.

Fig. 210.—Focus Lamp Holder.

Fig. 211.—Surgical Lamp.

of the other, this switch will be placed somewhere independently.

When a small resistance is required, say for arc lamps, Fig. 215 is a very usual form. The ring, shown on the slate cylinder, around which the wire is wound, is made movable in order that an accurate adjustment of the resistance may be obtained.

Fig. 216 is a neat form of resistance made by Messrs. Woodhouse & Rawson, and is known as the Wirt Rheostat, after the name of the inventor. Turning the barrel round, by means of the knob at the top, the value of the resistance can be changed at pleasure from the maximum capability of the instrument to zero. It is really nothing more than a very high resistance gramme ring, which has the insulation turned off it for a distance of half an inch to an inch

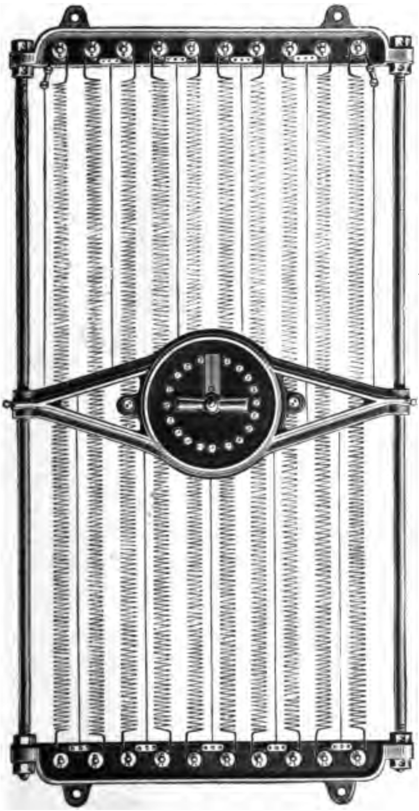


Fig. 212.—Goolden Resistance Frame.

Fig. 213.—Woodhouse & Rawson Resistance Frame. (Also Nalder's form.)

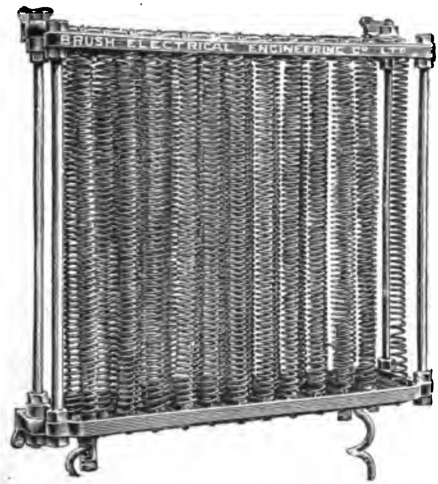


Fig. 214. —Brush Resistance Frame.

Fig. 215. —Arc Lamp Resistance.

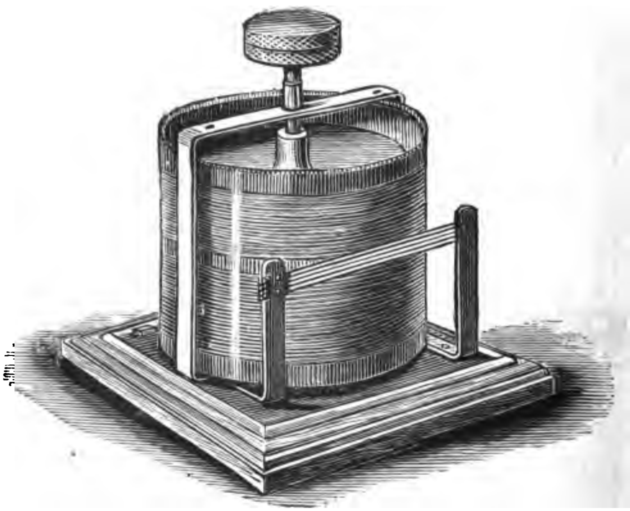


Fig. 216. —Wirt Rheostat.

around some part of its length; and upon this portion a contact-brush, or other form of contact-piece presses. The earlier gramme-ring dynamos possess armatures with a comparatively high resistance, and for many purposes these armatures could be converted into rheostats, the latter being only another name for an artificial resistance.

It may be of interest to know the manner in which the Wirt Rheostat is made. A piece of mill-board is formed into a cylinder upon a wooden core, which is placed in the lathe. The lathe being set in motion, insulated wire is coiled around this card support, and the whole is well coated with shellac. The wooden core is now removed and the cylinder pressed flat. It is now again formed into a cylinder, so that the wire resembles the roundabout of a squirrel's cage. The whole is mounted upon a metal framework capable of being rotated, and is insulated from the coil. The coil is now remounted in the lathe and revolved before a cutter, which removes the insulation from the wire; forming in appearance a bright band around the cylinder, half an inch or more in breadth, according to the current intended to be passed through the resistance. The rheostat is now mounted upon a base, a suitable form of brush pressing upon the portion just cleared from insulation, and the axis being connected with one end of the wire, while the other is left free. In use, the current enters the coil through the axis and passes out at the place in contact with the brush, the length of wire traversed depending upon the amount of rotation given to the cylinder.

There is a variety of forms of resistance-boxes intended for special uses, such as for medical purposes,

raising and lowering the lights of lamps, and similar requirements.

Where a very large current has to be passed through a resistance, liquid is frequently employed for reducing the pressure. These are generally made in the shape of an oblong tank, with one plate of metal fixed at one end, and another plate of metal which can be moved backwards and forwards, so that the amount of liquid between the two plates may be varied at will. When this form of resistance is used, gases in large quantities are evolved, unless the chemical nature of the liquid is such that any gas generated enters into some fresh combination which is soluble in the liquid. In any case water alone is too bad a conductor, and it must be acidulated slightly with sulphuric acid.

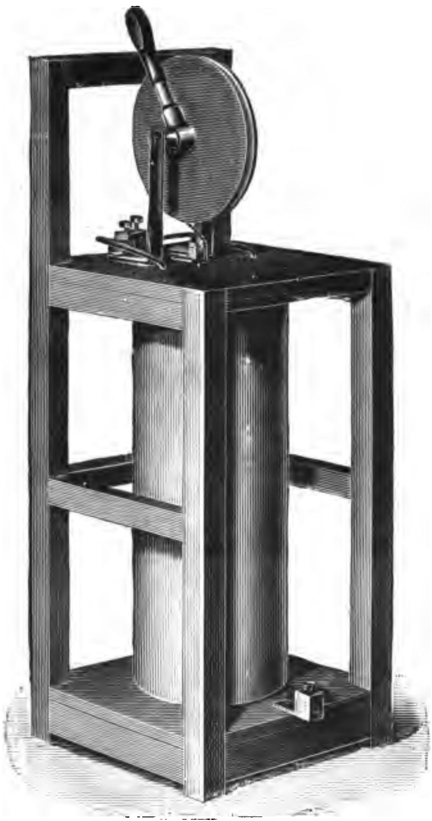


Fig. 217.—Liquid Resistance.

Fig. 217 illustrates a form of liquid resistance, in which a special chemical fluid is placed that does not give off gases when in use. There is a conical plate of lead at the bottom of the jar, and a cone of lead which may be raised and lowered by means of the handle at the top. The wooden pulley, whose position can be fixed by a turn of the handle, carries a cord, which is attached to the movable cone. This apparatus is supplied by the General Electric Company, and is largely used at the theatres.

With the alternate current the reduction of the pressure is an easy matter. Choking coils are used. The simplest form of such an apparatus is to coil a small portion of one of the leads around a bundle of soft iron wire, and this produces the desired result. The reduction of pressure can be regulated by adjusting the length of iron within the solenoid.

CHAPTER VII.

ARC LAMPS.

ARC Lamps scarcely come within the province of private house lighting, but since in some situations, such as in conservatories, they are occasionally employed, a word or two on this subject may prove useful.

In the mechanism of the arc lamp there has not been any great advance. This is what might have been expected, considering the simplicity to which the arc lamp has now been brought; and in the best forms a close approximation to perfection has been secured. Recently a lamp has appeared, in which the lower carbon is made tubular. This passage is kept well filled with a hydrocarbon, which becomes volatilised at the place where the arc is formed, resulting in a very steady and more agreeable light, and said to produce economy, although this may be questioned. The author has obtained an equivalent result in a very much simpler way, by placing a gas ring around the arc. This ring is nothing more than a large argand burner using coal-gas, whereby steadiness is secured and a yellow tint imparted to the light; which colour, for artificial lighting, appears still to be appreciated.

Everyone must have observed how similar the light of arc lamps is to moonlight. It is also well known that the light emitted from the arc is almost identical

with sunlight, and of course the moon's rays are nothing more than reflected sunbeams. All will admit that there is a great difference between sunlight and moonlight, although it would appear it is not a matter of the quality of the light, but simply a difference of brilliancy. It cannot, however, be denied that the sun appears yellow, while the moon is white. This may possibly give rise to the prejudice, if it is one, of preferring artificial yellow to white light.

The better known arc lamps are made by Messrs. Siemens, Messrs. Crompton, Messrs. Johnson & Phillips, and the Brush Company. The Brockie-Pell lamp (made by Messrs. Johnson & Phillips) is probably ahead of them all, as it burns with perfect steadiness and there are no liquid dash-pots. Messrs. Woodhouse & Rawson supply a pretty little lamp called "The Midget," intended for use with small currents, *i.e.* from 2 to 5 amperes. A small lamp of the same kind is supplied by the General Electric Company, and it works admirably. In all cases the pressure required for each lamp varies from 40 to 55 volts, or 60 to 65 volts in very large lamps; and the light in the case of an arc lamp is produced not by an incandescent filament lasting some 2,000 hours, but from two carbon rods placed in holders, their free ends, not in contact, being maintained at a high temperature by the passage of the current, which jumps this interval. In small lamps the space between the two carbon rods is 1-16th of an inch, and in large 1-8th to 1-4th of an inch, the passage of the current being indicated by a curved flame or "arc"; but the light is produced by the incandescence of the carbons at the point of separation.

A diagram of a 2,000 c.-p. arc is shown in Fig. 218, with the positive carbon uppermost, from a photograph

taken by the author by means of two nicol prisms at a distance of 16 inches from the arc.

The positive carbon burns hollow or cup-shape, and transfers carbon to the negative rod, which becomes pointed.

An arc lamp placed overhead should have the positive carbon uppermost, assuming that the carbons are vertical, so that the light is sent downwards from its incandescent cup. If this order is reversed, the bulk of the light will be sent upwards towards the ceiling or the sky. In rooms, therefore, where reflected light may be more desirable than too much direct light, the positive carbon may be lowermost with advantage. It is thus seen that the positive carbon must face the direction in which the light is to be thrown.

Fig. 218.—Electric Arc.

In order that the automatic feed of the carbons may be properly regulated, so that the length of the arc may be maintained constant, the adjustment screws for this purpose, which are attached to the mechanism of the lamp, must be attended to. The chief reasons why the arc lamps so often flicker are because the feed is irregular and the carbon impure or contains air cavities.

In air the positive carbon burns twice as fast as the negative. The arc flame is not visible electricity passing, but simply heated gases. Arc lamps require much attention, for it is necessary to clean and trim them with new carbons daily. As a rule the lengths of carbon employed last from six to eight hours, and in many instances the lamps hold two sets of carbons, the second set striking an arc automatically when the first have

burned out; in which case they will produce light for double the time.

Some protection is necessary against fire from falling pieces of incandescent carbon, also against wind, which might blow out the arc.

Globes and lanterns should always be protected by wire netting to prevent accident, in the event of their breaking from any cause. Such a globe is shown in Fig. 219.

An increased current greatly increases the light, the proportion of current to light not being direct, as in the case of glow lamps.

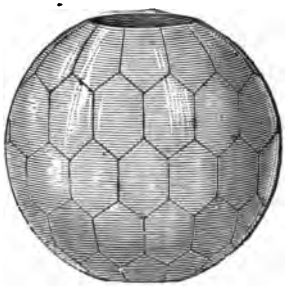


Fig. 219.—Protected Globe.

Alternate current arc lamps make a buzzing noise and work at an E.M.F. of 35 to 40 volts. No crater is formed, and both carbons consume at equal rates.

In order to start the arc, the carbons are made to touch one another for a moment and then separate. This is done automatically by the mechanism of the lamp.

Many persons imagine that the electric light gives no heat and are much puzzled when told that the electric arc is the highest temperature known at the present day. It is perfectly true that the arc light is cool for illuminating purposes, since the actual mass raised to so high a temperature is very small considering the enormous amount of light given out. It must also be borne in mind that arc lamps give off noxious nitrogenous fumes, which are very noticeable in confined situations. Glow lamps emit absolutely no fumes, as they are hermetic-

ally sealed in glass globes. On the other hand, they produce a considerable quantity of heat, but far less than gas or lamps, light for light; and difficult as it may be to believe, wax candles give more heat, light for light, than either of the latter named illuminants.

The *Electrician* of June 14, 1889, gives a paragraph from an interesting letter written by the late Sir C. W. Siemens, in respect to the comparison between the light-giving power of arc lamps and gas: "A very powerful arc light gives as much as 33 per cent. of the energy absorbed in the arc as luminous rays (25 per cent. measured horizontally), whereas Tyndall found a vivid gas-flame to yield $\frac{1}{25}$ of its radiant energy as luminous. But the $\frac{24}{25}$ is the loss only by invisible rays, and does not include the heat carried up through the chimney as heated air, which loss is not an invariable quantity, but amounts to at least four times the radiant heat. This makes the total heat developed in combustion of the gas $25 \times 4 = 100$ times greater than that sent out in the form of luminous rays."

By viewing the glowing surface of the positive carbon in such a way that its projected surface occupies a smaller area, it would appear reasonable to suppose that the amount of light for the apparent surface would be more intense at every point. But this is not so, for whether a luminous surface is looked at obliquely or not the intensity at every point is the same; because the more obliquely the rays are given off the less intense they are in accordance with a well-known law; so that there is no means known of increasing the intensity of the luminous surface beyond what it happens to be at the time. Reflectors, of course, will increase the quantity of light

in a given direction, but it is not in this sense the matter is being considered.

In the years 1882 and 1883 the writer tried many experiments with arc lamps. One of these consisted in creating the arc within glass globes and tubes. The results were successful for both alternate and direct currents, but the advantage gained was small compared with the trouble caused by glasses breaking when there was a draught; and to protect the glasses by second coverings of glass was to create a loss of light. This principle of burning the "arc" has been revived as new last year (1893).

Fig. 220.—Brockie-Pell Arc Lamp.

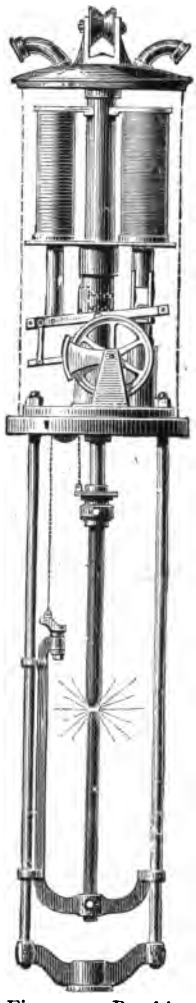


Fig. 221.—Brockie-Pell Arc Lamp (Interior).

The following illustrations are examples of arc lamps :—

Fig. 220 is a view of a Brockie-Pell

arc lamp suitable for 10 amperes and upwards, according to the manner in which the solenoids are wound.

Fig. 222.—Case for Brockie-Pell Lamp.

Fig. 221 is an illustration of the same lamp with the cover off. Briefly, it will be observed that the

mechanism consists of two solenoids and a little wheel apparatus below. The main current passes through one solenoid and actuates the lamp; the other solenoid has a high resistance and is placed in shunt, its function being to regulate. The wheel apparatus below is a brake and an air dash-pot, its use being to give a steady feed for the carbon.

Fig. 222 is one form of lantern case made for the Brockie-Pell lamp, and is suitable for out-of-doors. The majority of the manufacturers employ lanterns somewhat of this shape for one of their patterns.

Fig. 223 is another lantern case, adapted for use indoors. Both these lantern cases are shown open, ready for trimming the lamps.

Fig. 224 gives an illustration of a Brockie-Pell projector lamp. The details of this apparatus have been somewhat improved

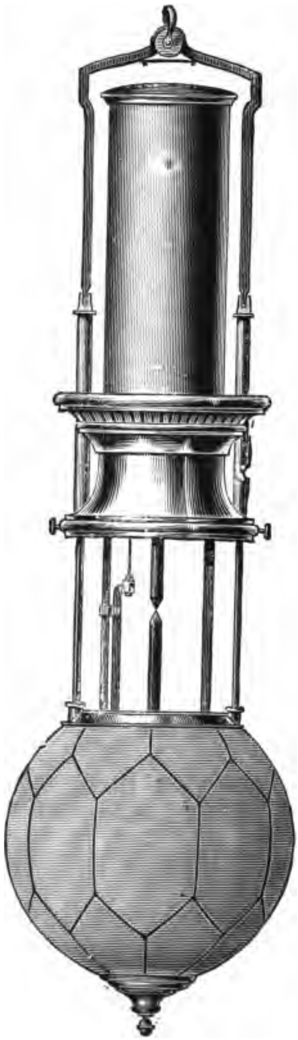


Fig. 223.—Lantern Case for Use Indoors.

by the author, in order to facilitate its use for the optical lantern.

This projector and other lamps have been largely employed by the writer, and from his experience he is

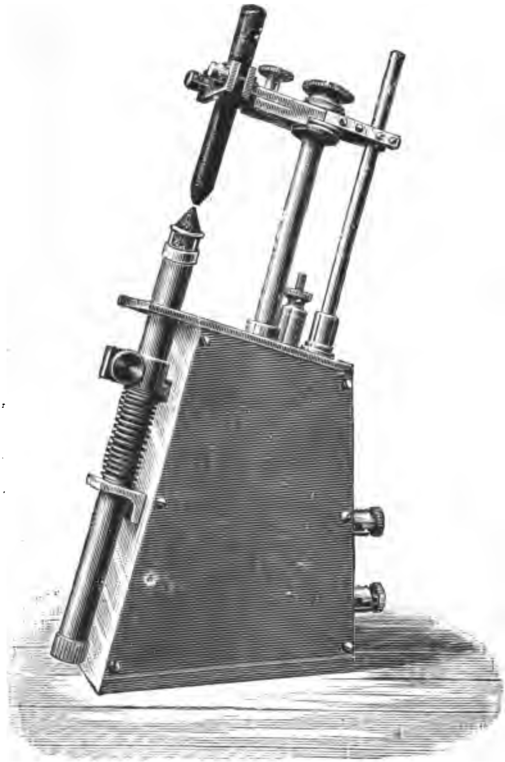


Fig. 224.—Brockie-Pell Projector Lamp.

fully justified in saying that he has never come across any lamp equal to the Brockie-Pell for steadiness, simplicity, and efficiency; besides, all the details of manufacture are carried out most conscientiously. Messrs. Johnson &

Phillips, the makers of these lamps, as a firm, as well as their manufactures, are so well known to the public that to say more in regard to their arc lamp is unnecessary.

Fig. 225 illustrates the "Midget" lamp of Messrs. Woodhouse & Rawson.

Fig. 226 shows four arc lamps connected in series.

Fig. 227 illustrates the appearance of a Brush lamp, with two sets of carbons. In this lamp the dash-pot contains glycerine.

This lamp is so largely in use that a view may be given of the interior. Fig. 228 is a view with portions of the interior shown in section. It will be observed that each carbon supporting rod is hollow at the upper part. In the hollow a piston works, its rod being attached to the upper end of the tube above. This portion of the carbon holding rod is filled with glycerine, and the object is to obtain a steady feed. The glycerine dash-pot is also seen. The small diagram below represents the mechanism for changing over to the second pair of carbons when the first pair is burned out. It will be noticed that there is a washer on each rod, and the lifting-piece in the centre is shown in such a position that the washer on one rod is askew; consequently this rod is held fast. When the carbons

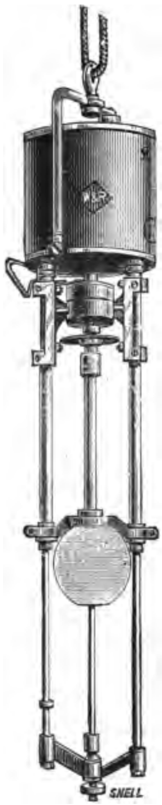


Fig. 225.—"Midget" Arc Lamp.

change over, the washer is permitted to assume a level position, leaving the rod free to act.

Fig. 229 is another view of the interior; E E[1] being

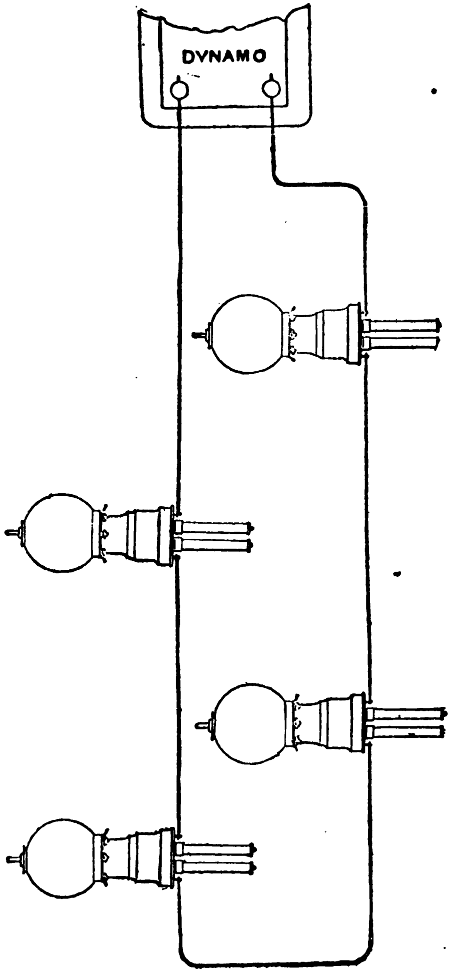


Fig. 226.—Arc Lamps in Series.

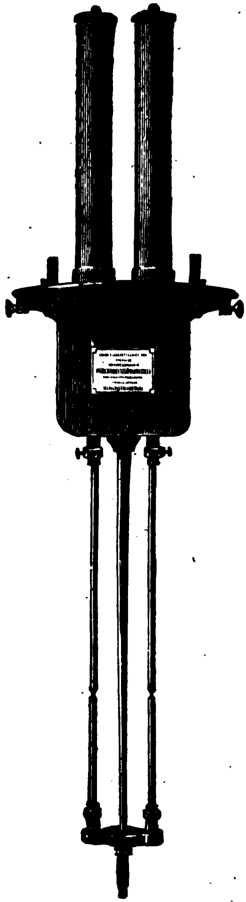


Fig. 227.—Brush Lamp (2 sets of carbons).

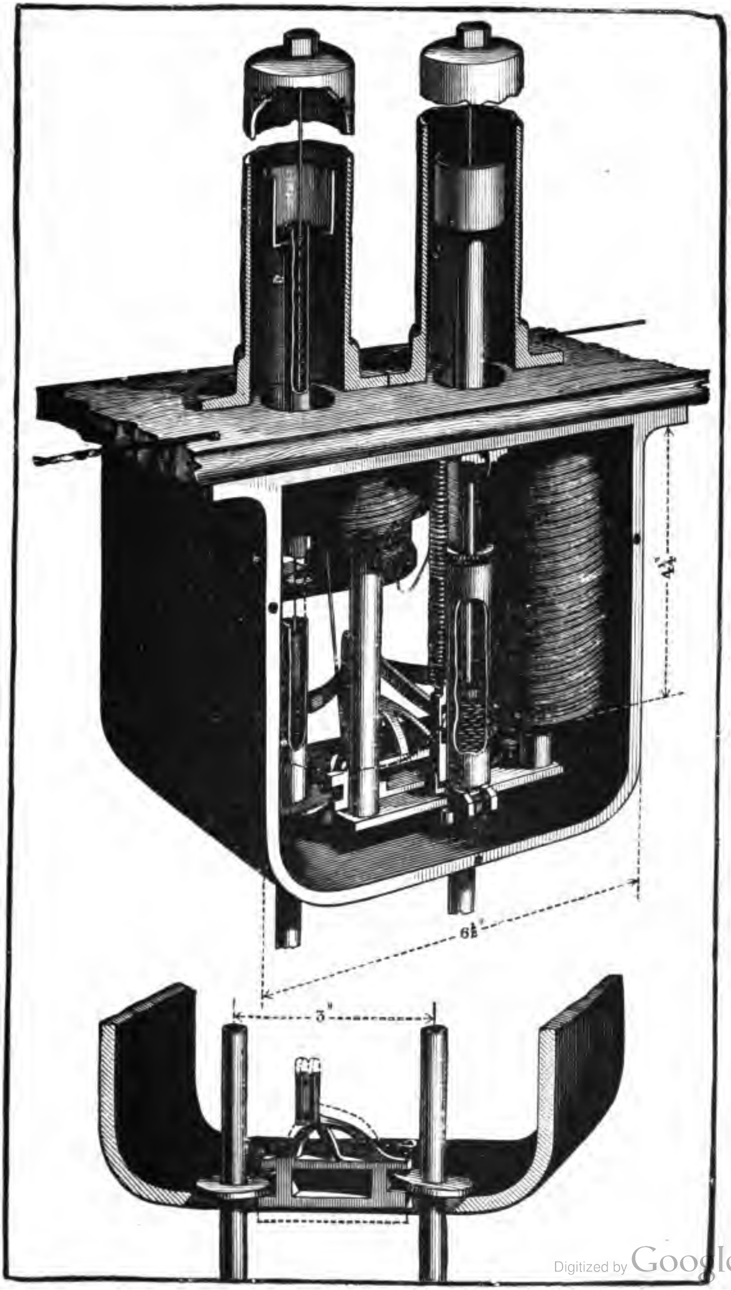


Fig. 228.—Interior of Brush Lamp.

the rods, and D the cut-out coil which acts when the carbons are burned out or should the lamp fail from any cause. The current is conducted to the carbons by means of the little brushes which rub on the rods, as seen in the figure.

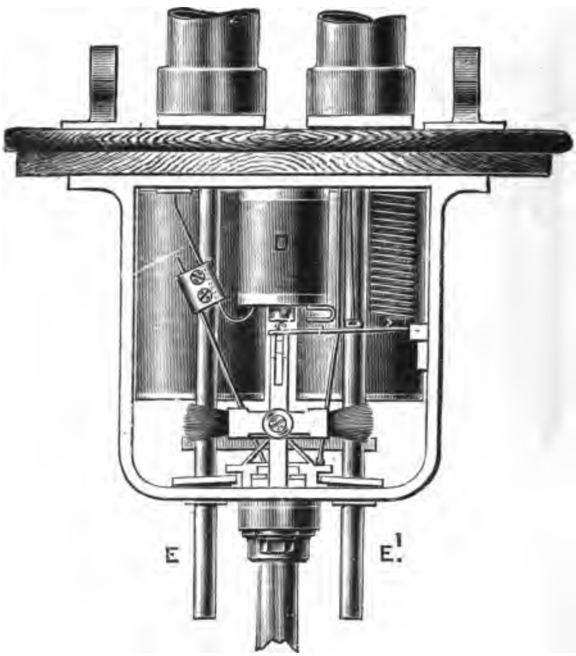


Fig. 229.—Interior of Brush Lamp.

Fig. 230 is the Byng inverted form of arc lamp, supplied by the General Electric Company. The light given by this lamp is very pleasant. The lower part of a room is lit by the light reflected from the ceiling, so that no strong shadows are produced.

There also exists a ceiling plate made by the General Electric Company, and so arranged that the lamp may be raised and lowered, the leads being disconnected at the ceiling or other fixed point. Consequently long loops of lead are avoided.

Fig. 230.—Byng Inverted Arc Lamp.

Fig. 231 represents Paterson & Cooper's new 5-ampere arc lamp, intended chiefly for indoor use.

Fig. 231.—Paterson & Cooper's Small Arc Lamp.

Prof. Silvanus Thompson's writings should be studied for detailed descriptions of arc lamps.

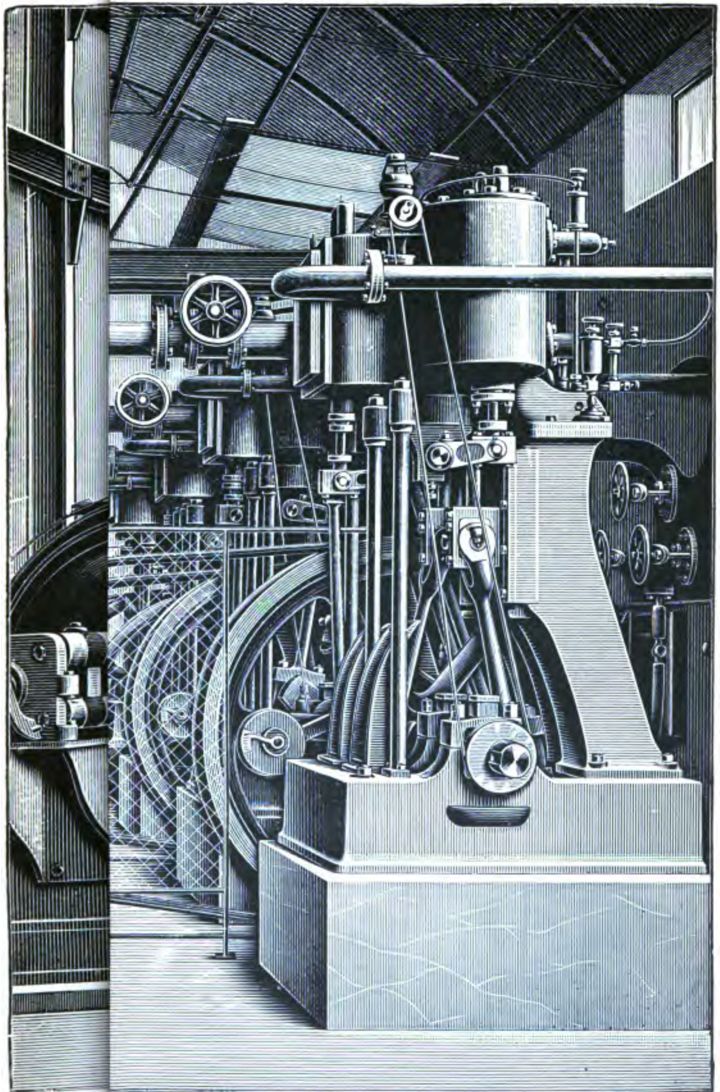
CHAPTER VIII.

PRACTICAL APPLICATIONS.

THE engineer and expert have, as a rule, a general knowledge as well as experience of the numerous practical ends which electric energy may serve. The general public are still very ignorant on the point: indeed the same may be said of experts who, for some time past, have practised their vocation in less civilised parts of the world. This must plead the only excuse for including a chapter on the subject. Previous experience has shown that this book falls into the hands of many persons who are seeking information in electrical matters, so that the number of plates, illustrating what may be done when electric energy is available, may not prove unwelcome. To give a full account of all the details necessary for installing these apparatus will be superfluous, for the information can be gathered from various portions of these volumes. In most cases also instructions are sent out with the apparatus.

The illustration (Fig. 232) gives a general idea of the appearance of a central lighting station on a moderate scale, when the current generated is of the alternate type. It is a view of the Bath central station, erected by the Brush Company.

Fig. 233 represents a small central station, worked by water power, at Lynmouth.



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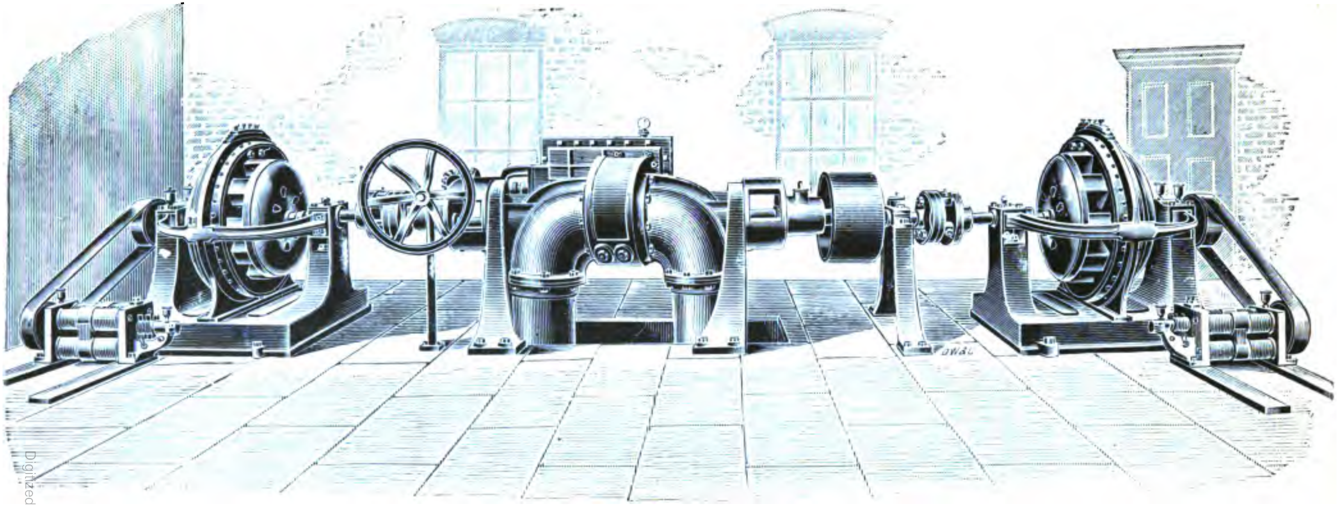

Fig. 233.—Lynmouth Water Power Station.

Fig. 234 shows an overhead traveller, worked by means of a motor.

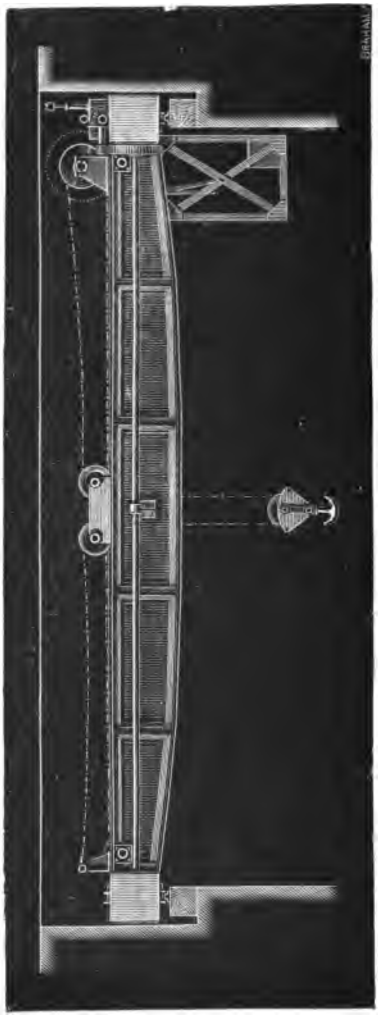

Fig. 234.—Overhead Travelling Crane.

Fig. 235 is a capstan on board a ship, and worked by a motor.

Fig. 236 is an electric mining locomotive.

Fig. 237 represents an electric launch, in plan and section. The accumulator is placed under the seats. These launches attain a speed of about six miles an

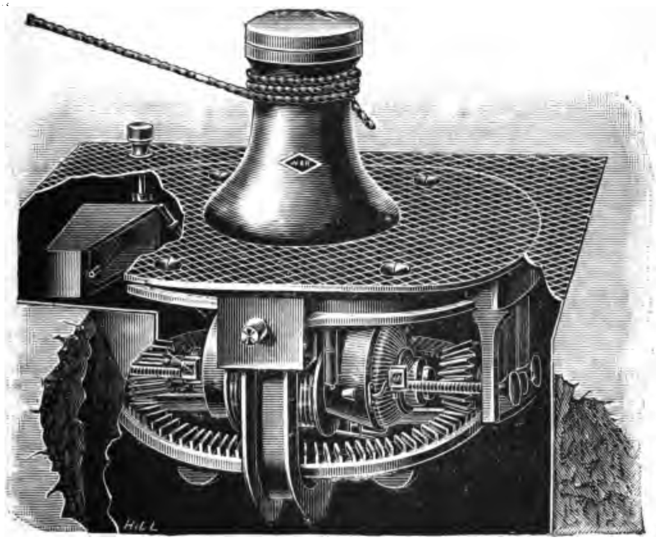

Fig. 235.—Capstan.

hour, and when charged can make a nine or ten hours' trip.

Fig. 238 illustrates the general appearance of an electric launch.

Fig. 239 is an electric hoist.

Fig. 240 shows an electric omnibus.

Fig. 241 illustrates a portable apparatus for producing

Fig. 236.—Mining Locomotive.

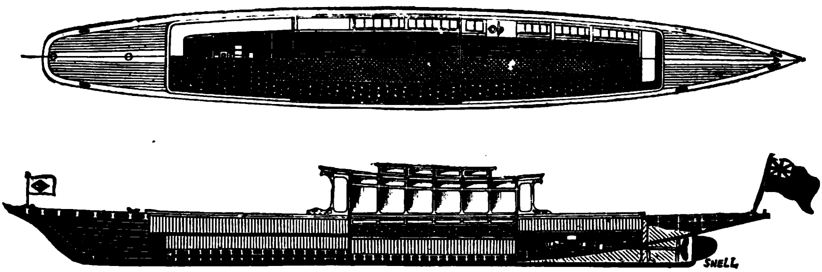

Fig. 237.—Electric Launch, Section and Plan.

the electric current. It consists of a boiler and steam-engine connected to a Brush "Arc-lighter."

Fig. 238.—Electric Launch.

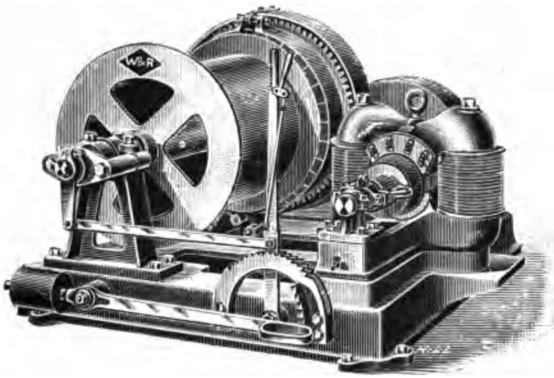

Fig. 239.—Electric Hoist.

Windmills have been used for working a dynamo to charge an accumulator. Naturally such an apparatus could be used only in exposed places, where a good deal of wind exists.

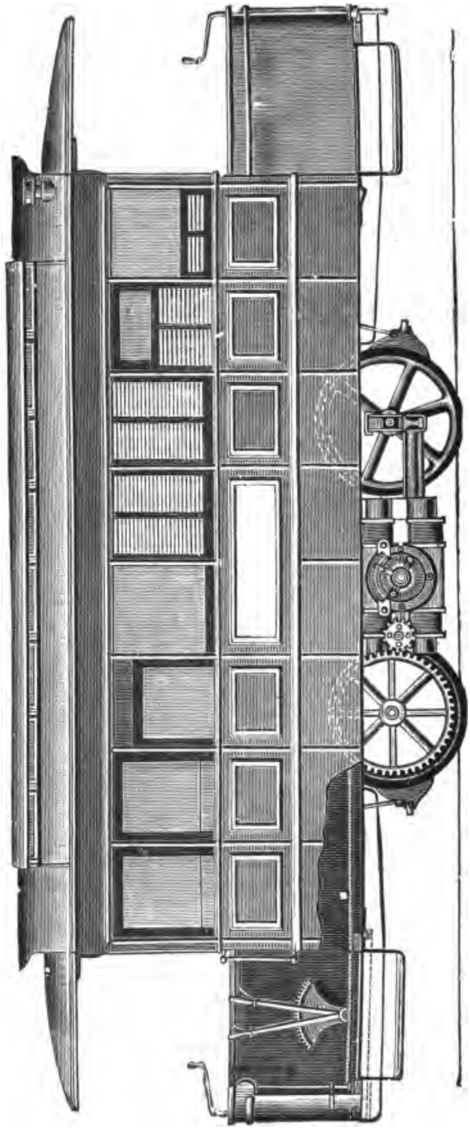

Fig. 240.—Electric Car.

Figs. 242 and 243 give a general idea of the application of a motor to a large and to a small pump.

Fig. 241.—Portable Engine and Dynamo.

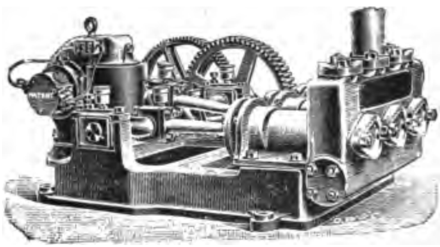

Fig. 242.—Pump with Enclosed Motor.

Fig. 244 shows the manner in which a projector is suspended from the bow of a ship.

Fig. 245 shows a hand projector suitable for a current of 100 amperes.

Fig. 246 illustrates a ship passing through the Suez Canal at night using a deck projector to find her way.

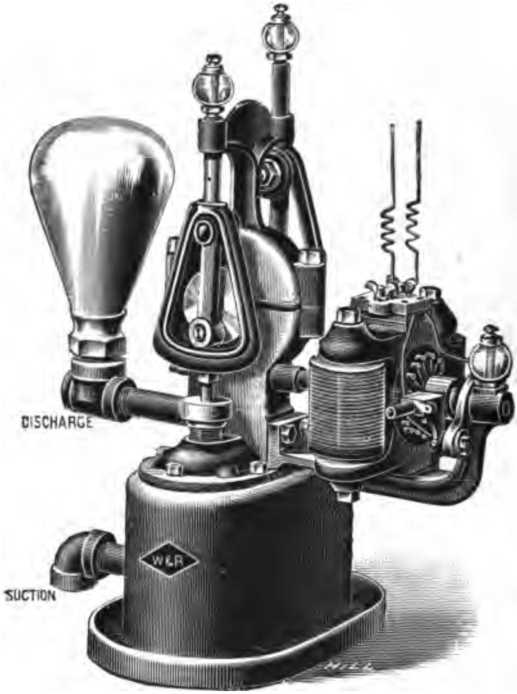

Fig. 243.—Electric Pump.

The following two figures, 247 and 248, show the Crocker-Wheeler motor as applied to a small pump and a fan.

Fig. 249 is a novel adaptation of a motor to a lathe. The armature, it will be observed, is mounted upon the mandrel. Drills also have been mounted in this way, but the author prefers the motor separate from the tools.

There is no limit to the use to which small motors may be applied, whether to mechanical pianos, toys,

Fig. 244.--Ship Projector.

Fig. 245.—Hand Projector.

mechanical appliances needed in domestic requirements, for laboratory purposes, or any small machine requiring motive power.

Fig. 250 is a representation of the writer's Electric Lantern. The lantern case has three fronts, two of

which are seen in each figure. The microscope, the polariscope, and the plain front are shown. The electric arc is admirable for exhibition purposes, as well as for study.

Figs. 251 and 252 indicate how ventilating fans may be worked by means of motors.

Fig. 253 is a view of an electric mining-drill.

Fig. 254 represents a small dynamo worked by a water motor.

Fig. 255 illustrates the Telpher Railway, as designed by the late Professor Fleeming Jenkin. Professor Perry has also assisted in bringing out this system.

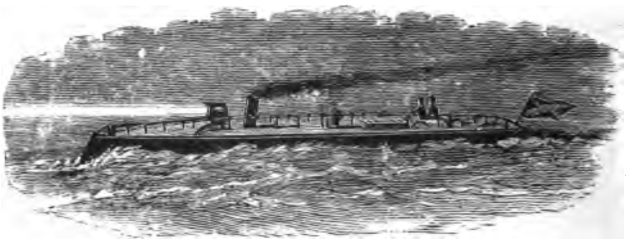

Fig. 246.—Projector on Ship.

Fig. 256 represents a motor driving a flexible shaft, the end of which carries dental tools. The switch on the wall is to regulate the speed. These are made in America and supplied by the General Electric Company. This tool is exceedingly useful for engraving purposes.

Figs. 257 and 258 show a mangle and a hairdresser's brush, driven by a motor.

The following also show a few further practical purposes to which the electrical energy may be put. The majority of these apparatus are supplied by Messrs. Crompton, and it will be noticed that this firm use the

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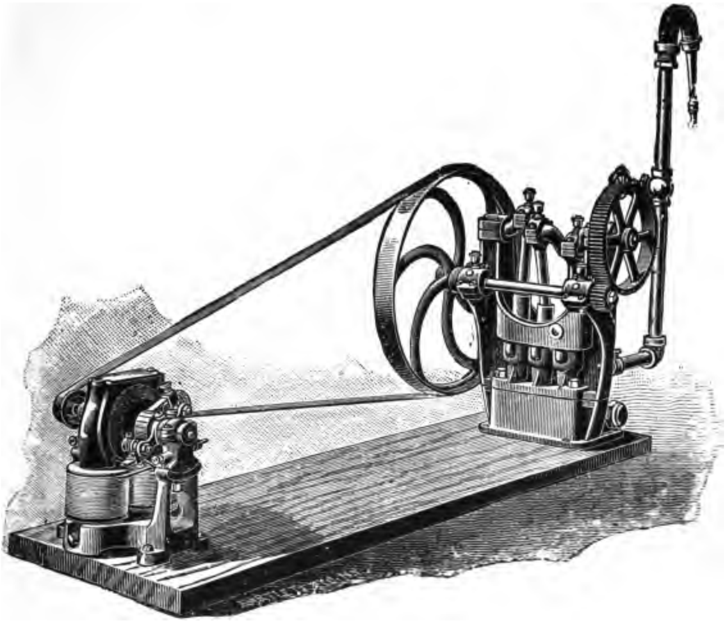

Fig. 247.—$\frac{1}{6}$ H.P. Electric Pump. (Crocker-Wheeler.)

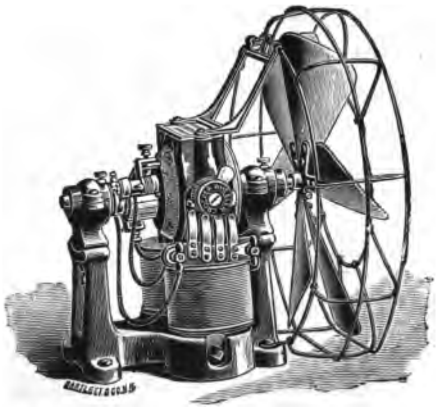

Fig. 248.—$\frac{1}{8}$ H.P. Electric Fan. (Crocker-Wheeler.)

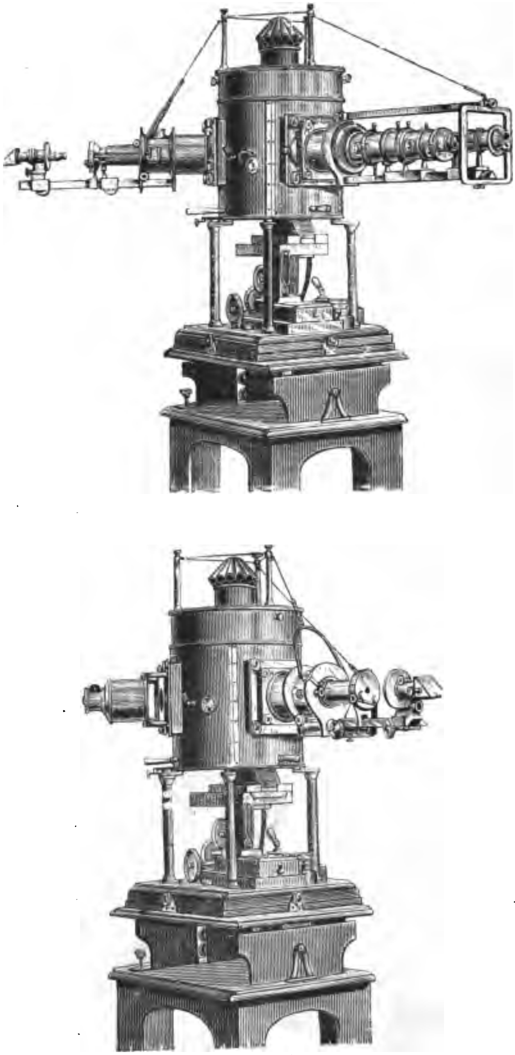

Fig. 250.—Electric Lantern.

Crocker-Wheeler motor. When slow-running direct is required off this motor, Messrs. Crompton add a worm-wheel gear, as illustrated in Fig. 259.

Fig. 260 represents a mixer, as used in most kitchens.

Figs. 261 and 262 show two forms of knife-cleaning machines worked by motors.

Fig. 263 is a boot-cleaning machine.

In a private installation part of the power may be used for the estate shops, churning, pumping, ventilating or any other work, and even for the production of cold

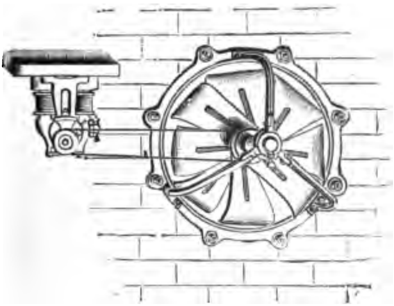

Fig. 251.—Electric Fan with Direct Motor Current.

Fig. 252.—Electric Fan with Alternate Current Motor.

air in summer; in short, there is no limit to the use which may be made of an electric motor for household purposes, and without noise, dirt, smoke, or disagreeableness of any kind.

The two frontispieces show the writer's workshop, where the method of employing motors to various tools can be seen.

The motor also occupies a very small space, and can be put anywhere; for only two wires are required to lead to it in order that it may give power. A switch only is needed to start and stop.

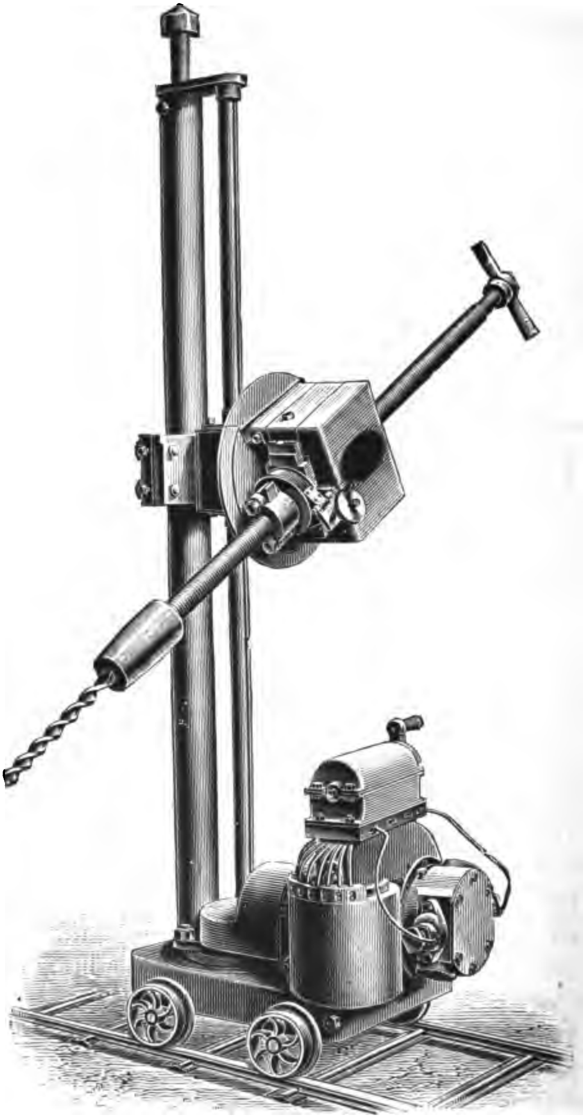

Fig. 253.--Electric Mining Drill.

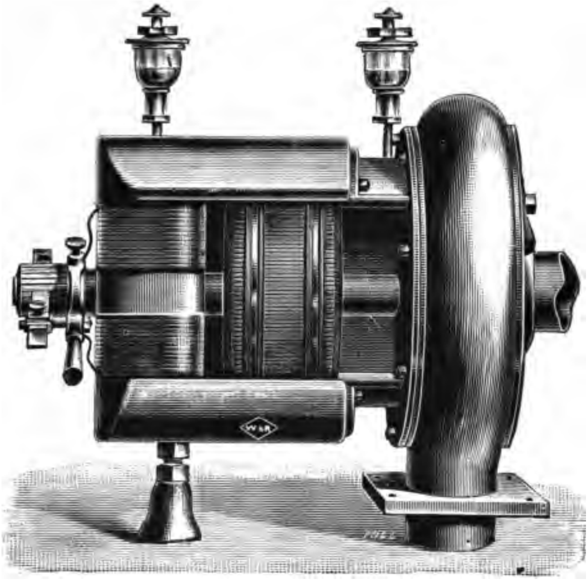

Fig. 254.—Dynamo and Water Motor.

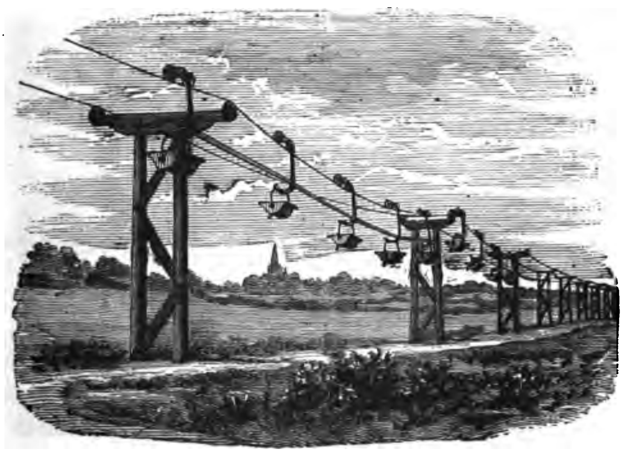

Fig. 255.—Telpher Railway.

There is a very large application of the heat-producing property of the current, which is gradually being taken advantage of. The General Electric Company

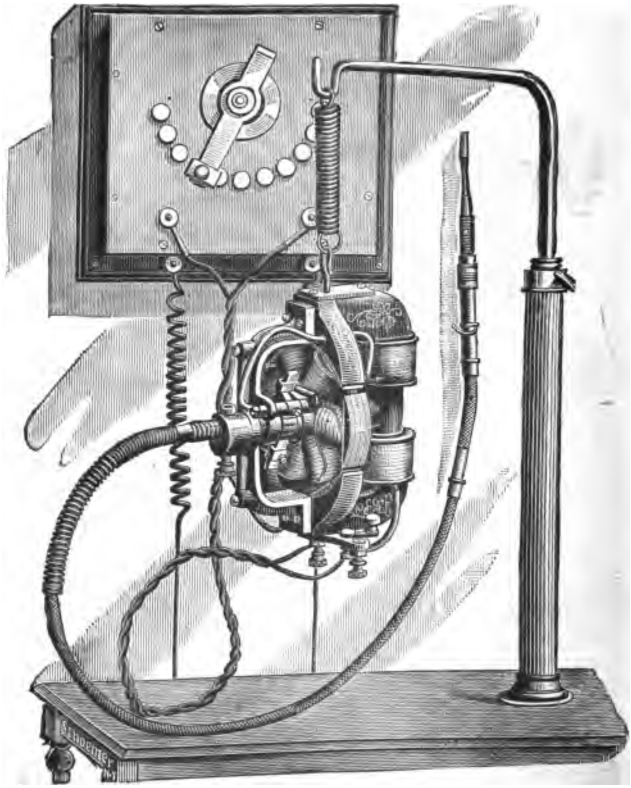

Fig. 256.--Dentist's Tool.

and Messrs. Crompton have led the way in this matter. Messrs. Pyke & Harris are also doing work of this nature, some of the apparatus having been designed by that firm and some by the author. The following

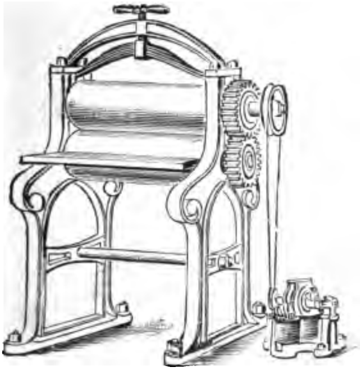

Fig. 257.—Electric Motor Driving Mangle.

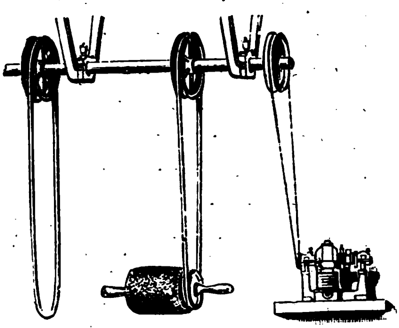

Fig. 258.—Electric Hair Brushing.

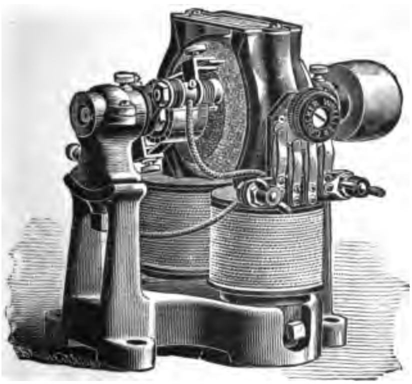

Fig. 259.--Crocker-Wheeler Motor.

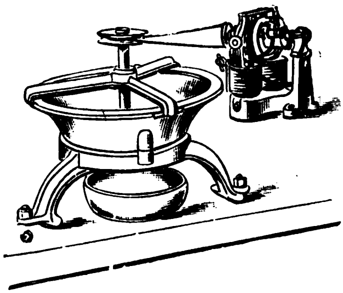

Fig. 260.—Mixer and Motor.

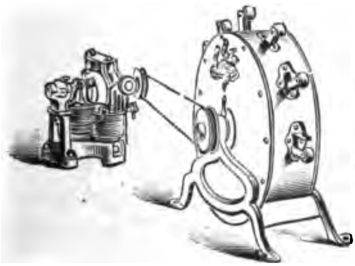

Fig. 261.—Knife Cleaning by Motor.

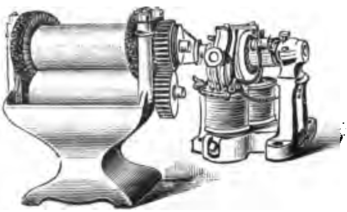

Fig. 262.—Electric Motor Driving Roller Knife Cleaning Machine.

apparatus give the general appearance of the productions of the General Electric Company.

The electric current produces the required heat by passing through very long and thin wire embedded in enamel, which combination may be termed a "heating plate." They are really nothing more than very high resistances suitably made for the purpose required. Many other

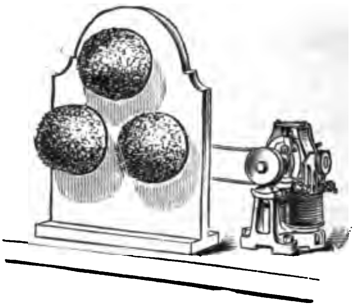

Fig. 263.—Electric Boot Cleaner.

Fig. 264.—Tea Kettle.

heating utensils, such as ovens, pots, pans, and the like, are made by this firm, besides the articles here illustrated.

Fig. 264 is a view of a kettle.

Fig. 265 is a saucepan for milk, having an inner lining. This is very suitable for warming invalids' and children's food.

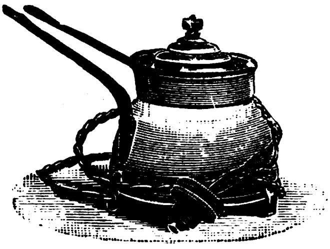

Fig. 265.—Saucepan.

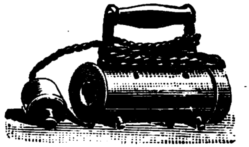

Fig. 266. —Curling Iron Heater.

Fig. 266 is a heater for ladies' curling-irons. The tongs are pushed into the axis of the apparatus.

Fig. 267.—Tailor's Iron.

Figs. 267, 268 and 269 show four kinds of irons, viz.: a tailor's goose, an iron for hats, an ordinary domestic flat-iron, and a billiard-table iron. The billiard iron also shows the improved form of plug to avoid projecting pins, which might create an accidental short-circuit.

A glue-pot is illustrated in Fig. 270.

Fig. 271 is a frying pan.

Fig. 272, a chafing dish.

Fig. 273, a stewpan.

Many of the above are made also in an ornamental form.

The following are some of Messrs. Crompton's productions. These designs are jointly those of Mr. Crompton and Mr. Dowsing.

Fig. 268.—Polishing Iron.

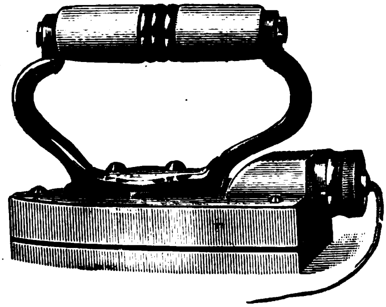

Fig. 269.—Flat Iron and Billiard-table Iron.

Fig. 270.—Glue Pot.

Fig. 271.—Frying Pan.

Fig. 272.—Chafing Dish.

Fig. 273.—Copper Stewpan.

Fig. 274 shows an electric oven. In this there are several heating plates; one or more may be used at pleasure, according to the heat required. The electric oven is

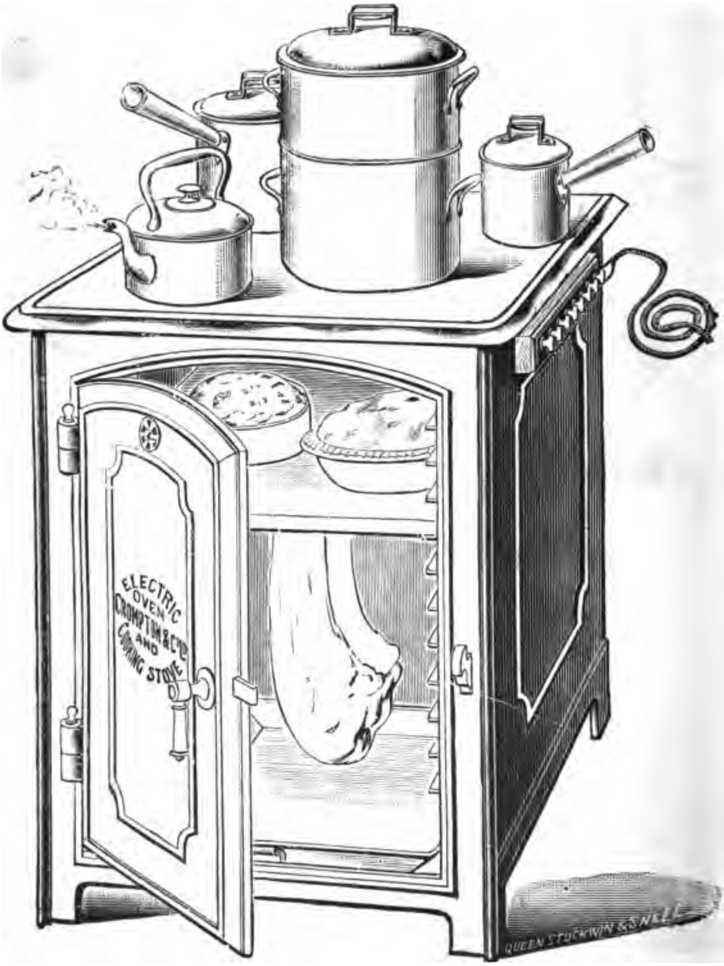

Fig. 274.—Crompton Electric Oven

economical, because when once it is hot the current may be greatly reduced and the temperature will not fall.

Fig. 275 is an ornamental electric kettle.

Fig. 276, a curling-iron heater, with the iron in place. It is very similar to Fig. 266.

Fig. 277, a shaving-pot.

Fig. 278 shows an ornamental warming plate for heating a room. Many modifications exist to attain the same end.

Fig. 279 is a bronchitis kettle.

Fig. 280 is a billiard-table iron.

Fig. 281 is a hot plate.

Fig. 282 is a foot-warmer.

Fig. 283 represents the electric churn arranged by the author and in use at his country house.

The majority of domestic heating apparatus, which are used, as a rule, with 100-volt currents, require from 2 to 5 amperes to

Fig. 275.—Electric Kettle.

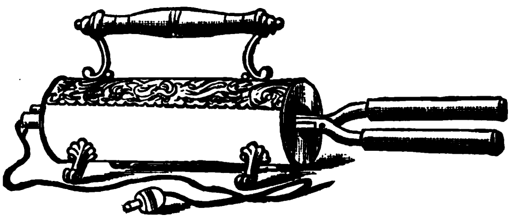

Fig. 276.- -Electric Curling Iron Heater.

work them. A kettle taking 5 amperes will boil three pints of water in about eight minutes. A flat-iron

generally requires from 2 to 3 amperes and in two minutes is hot enough for use. In the case of kettles, naturally so long as the current is on, there must be water in them; otherwise the bottom will be burned out, as with an ordinary kettle placed on a fire or on a gas stove. With regard to a flat-iron, the current must be turned off as soon as the proper heat is reached. As for the oven, each plate (generally there are three or four of them) will take from 5 to 7 amperes.

Fig. 277.—Electric Shaving Pot.

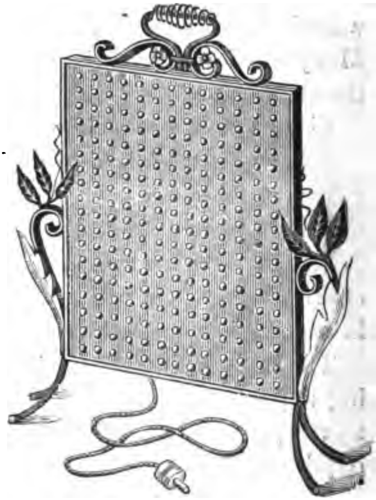

Fig. 278.—Electric Heater.

It is, therefore, evident that, with current at 6*d.* per B.T.U., the expense of boiling a few pints of water, or cooking a chop, or for any other domestic requirements where heat is needed, is very small and the convenience very considerable. In any room where a wall-connector exists, all that is necessary is to connect to it the apparatus, whatever it may be, by means of a flexible wire, by inserting a plug. The author has always insisted on the desirability of placing a switch to every

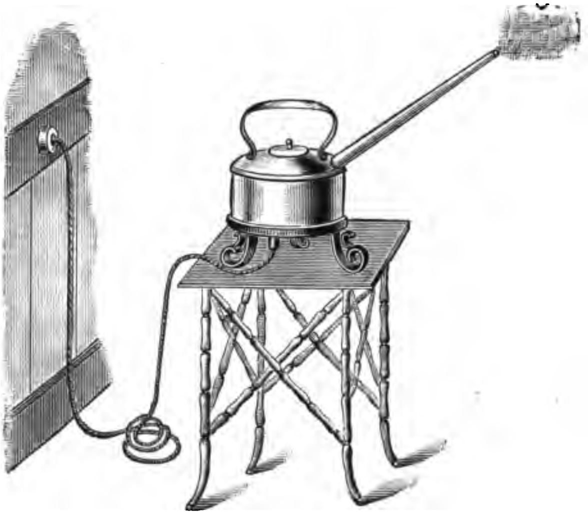

Fig. 279.—Bronchitis Kettle.

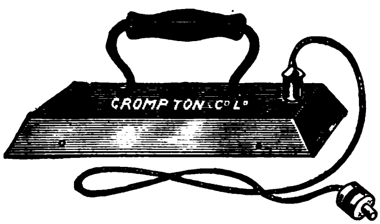

Fig. 280.—Billiard Iron.

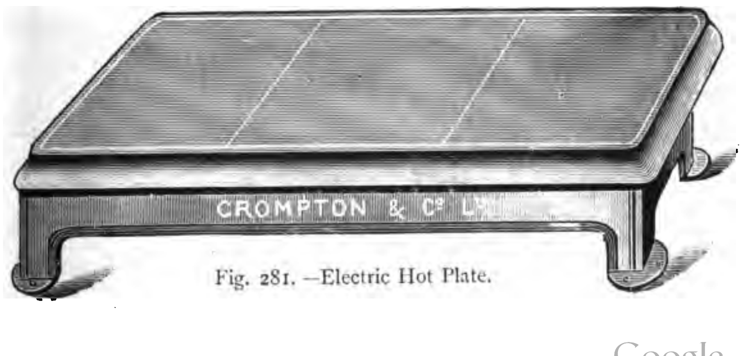

Fig. 281.—Electric Hot Plate.

wall-connector: a matter so often neglected. But it is obvious that, where these domestic appliances are intro-

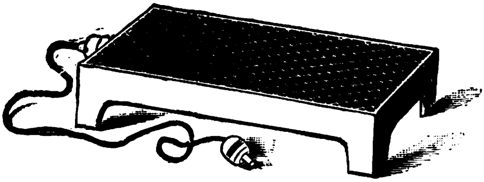

Fig. 282.—Electric Foot-warmer.

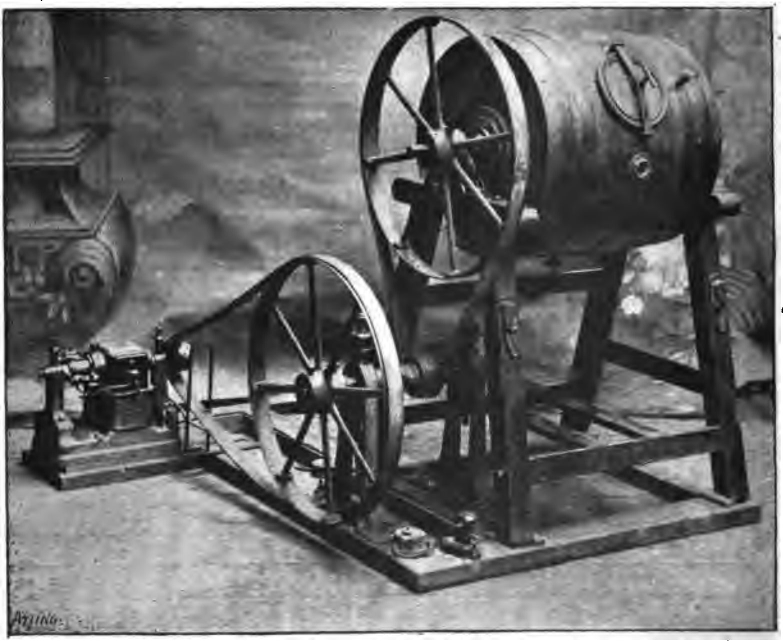

Fig. 283.—Electric Churn.

duced, such a switch becomes absolutely necessary, since in most cases there is no means of turning the current

off at the apparatus. To withdraw the plug from time to time, with large currents flowing, is unadvisable.

Naturally the boiling and other apparatus could be made to work much more rapidly by employing a larger current; but in the majority of cases the wiring in a house would not permit of such large currents being used.

The writer employs these electric apparatus extensively and finds them most practical, as well as being serviceable and clean. The chief modifications introduced by him are of a nature to adapt the electric current to household utensils as they at present exist.

Special furnaces are made for use with the alternate current, but they have not been much employed.

There is a great tendency in these days to be trammelled by gas precedents. In so many houses are seen electroliers and brackets following closely on the line of those used for gas. One would have thought that with a new illuminant some ingenuity would have been exercised to make a complete departure from the old system. In fact, the fewer fittings used and the more the lamps are distributed about the room, the better is the general appearance and the less the number of lamps required to produce the necessary light.

The following are a few illustrations of electric-light fittings. No attempt can be made to cover this branch of the subject within the limits of the present work, for there are tens of thousands of designs in existence and every individual must be left to suit his own taste.

Fig. 284 is a pendant with a fringe of transparent beads to subdue the light.

Fig. 285 is a bracket with pendant, the shade being made of semi-transparent celluloid.

Fig. 286 illustrates another form of bracket.

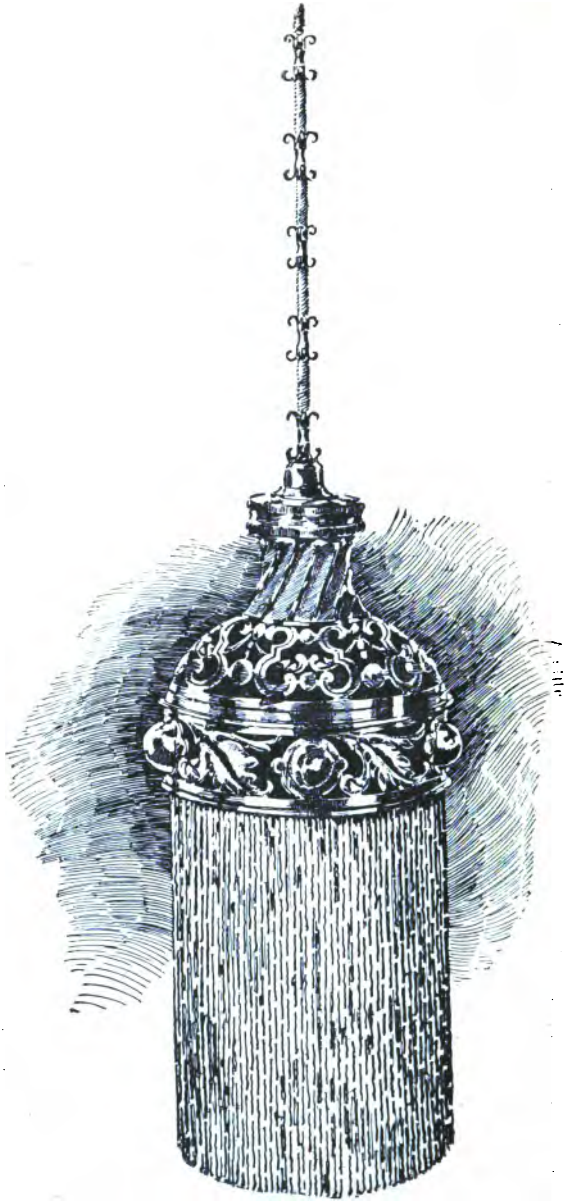

Fig. 284.—Pendant.

Fig. 287 shows a movable bracket hung on a picture rod, flexible wire being connected to a wall-connector or ceiling-plate at some point.

Fig. 288 represents a standard, the shade of which can be inclined. Such a motion is very often convenient.

Fig. 289 shows an adaption of the electric light to represent candles.

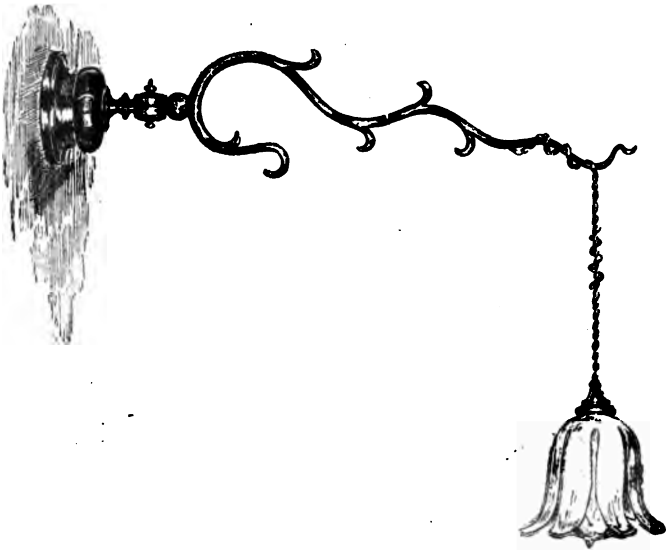

Fig. 285.—Bracket.

Fig. 290 shows another design of bracket.

Mr. Taylor Smith has brought out some of the prettiest designs which are to be found in the market. So have Messrs. Faraday. Messrs. Laing, Wharton & Down, Messrs. Verity, Messrs. Osler, and many other makers have also produced designs in very good taste.

A new (patented) fitting, shown in Figs. 291 and 292, has been devised by the author, and manufactured by

Messrs. Faraday. They meet a particular want, which had not been supplied. The principle is simplicity

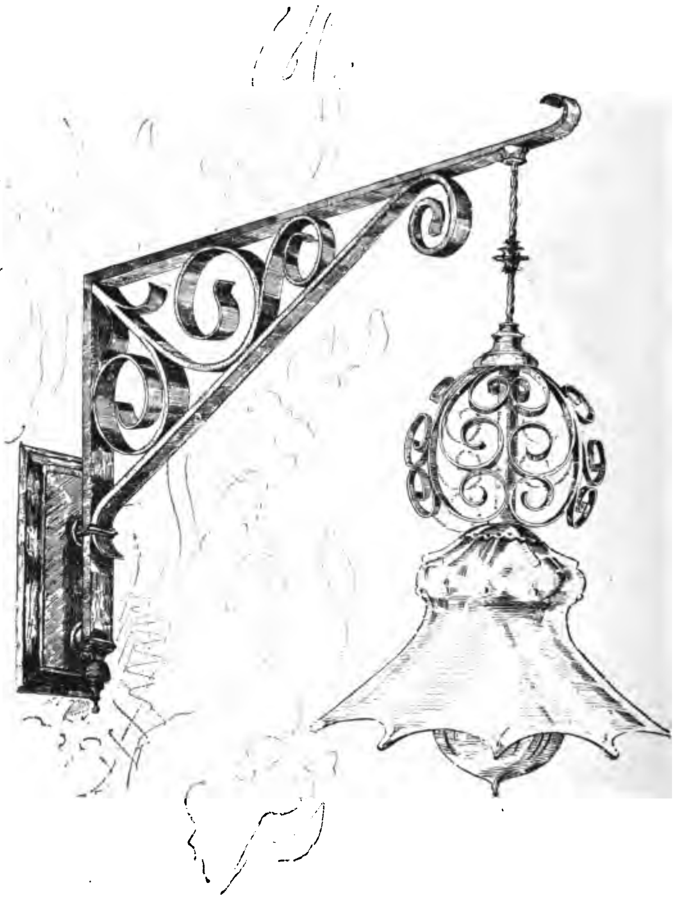

Fig. 286.—Bracket.

itself, as it permits a lamp to be fixed in a shade which can be adjusted at all angles, merely by placing the shade as required; there it remains, and it

may be pulled up and down at pleasure. Each lamp so fitted avoids the necessity of two or three lights for

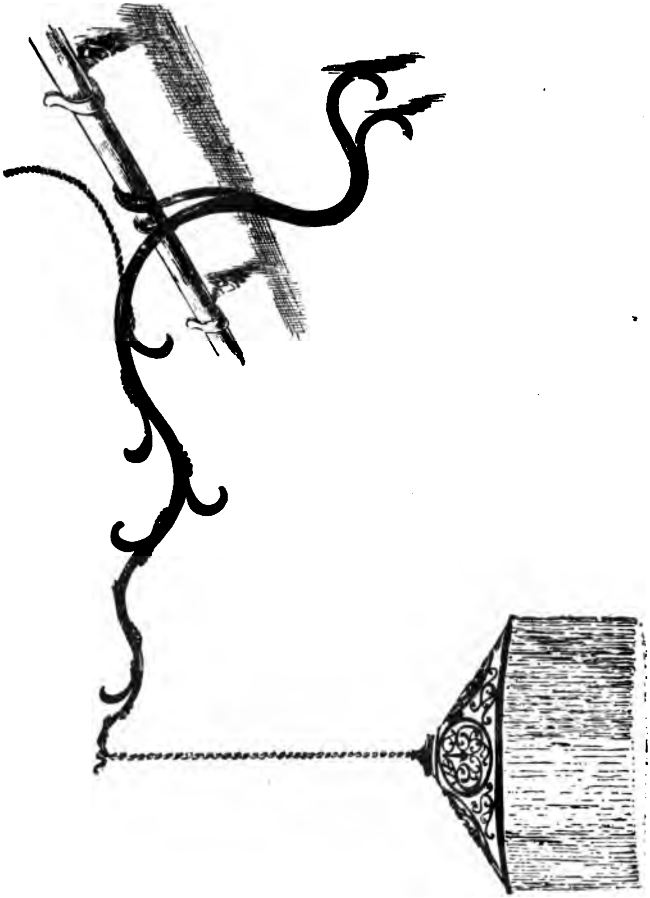

Fig. 287.—Movable Bracket.

writing-tables, work-benches, and so forth. The eyes also are shaded, when desired. This lamp has been called by the makers "The Perfect."

These pendants are now made in many other orna-

mental and graceful forms. For picture reflectors the shade is replaced by gilt shell, white enamelled or silvered inside; and the method of suspension lends itself most conveniently to that purpose. Miniature ones

Fig. 288.—Standard, with Inclined Shade.

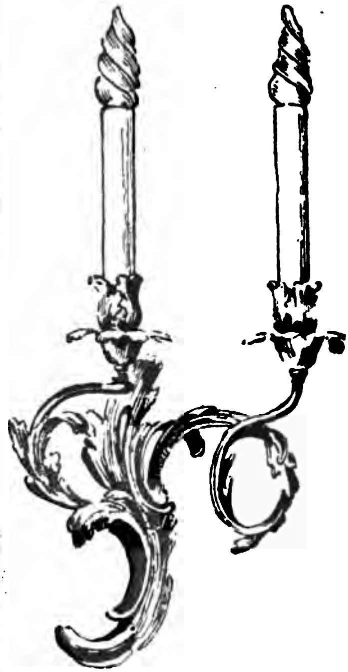

Fig. 289.—Electric Candle Bracket.

are also made for the toilet table. Reflectors for photographing by electric light are generally suspended on this principle. The ceiling plate is now replaced by the author's design of wall-connector, which has been

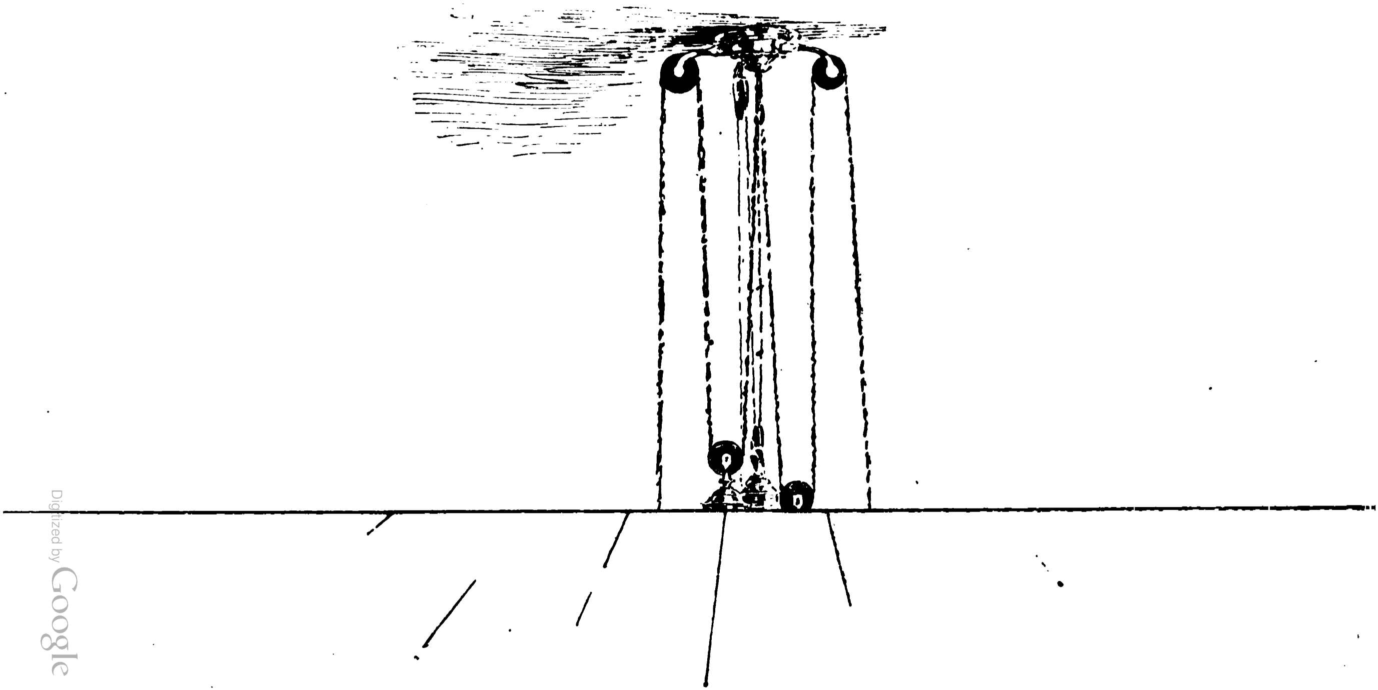

Fig. 291.—Sir D. Salomons' "Perfect" Canting Pendant. (Simple Pattern.) [to face p. 311.

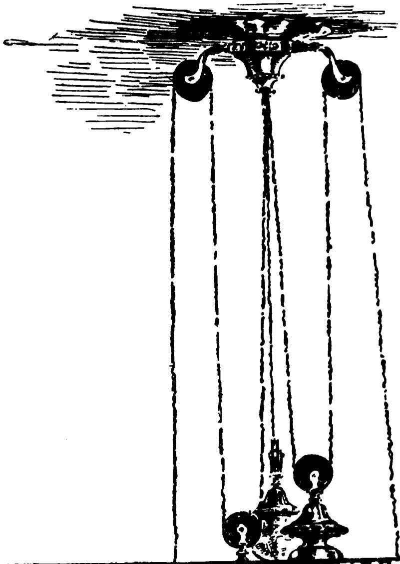

Fig. 292.—Sir D. Salomons' "Perfect" Canting Pendant.
(Ornamental Pattern.) [to face p. 311.

called "The Universal," a ring being added with three spokes, which bear the pulleys, so that the pendant may be taken down at any time.

For hammered copper plate no work has excelled that produced by Messrs. Laing, Wharton & Down.

Fig. 290.—Bracket.

A portable protected cellar lamp is shown in Fig. 293.

In Mr. Taylor Smith's portable lamps there is a reel in the base and a handle below, which enables any loose wire to be coiled up in the base. Many devices can be employed when the alternate current is supplied. To give an idea of one, a small combination transformer has recently been brought out by Mr. Pyke and the writer. This is shown in Fig. 294, in section and in plan. The letter E is the wooden reel, with grooves for the winding of the primary F and secondary G. Letters A and B apply to the socket, and C to the holder; D is the supporting tube. The terminals H, and a tube T attached are shown. The whole is encased by being wound round with wire on the outside, this wire passing through the inside also. The transformer is made by Messrs. Pyke & Harris, supplied by the General Electric Company, and intended to be inserted in an ordinary lamp-holder.

With the expenditure of no more current than is necessary for an 8 or a 16 c.-p. incandescent lamp, a number of vacuum tubes can be made to glow. For conservatories they look very pretty. There is also a large field for their use in the laboratory and for advertisement purposes.

The author has carried this principle still further in applying vacuum tubes to the figures on a clock dial for

Fig. 293.—Portable Cellar Lamp.

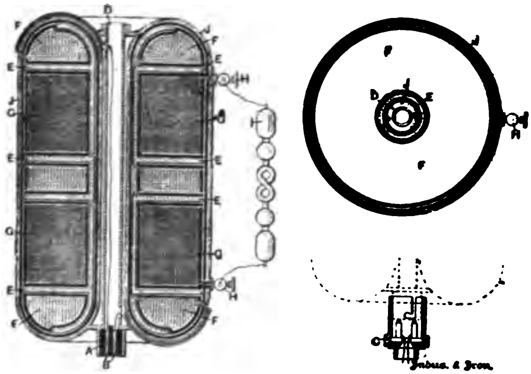

Fig. 294.—Salomons and Pyke Combination Transformer.

illumination at night: thus playing the double part of showing the time and acting as a night-light when the clock is made on a small scale. Many modifications of this arrangement exist.

To most minds hundreds of ideas will suggest themselves as to what electric energy can be made to produce for practical utility and for pleasing the eye. Electric cigar-lighters, electric weighing-machines, and electric medical apparatus, count as only a few among an endless number.

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